

## PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2000-022271

(43)Date of publication of application : 21.01.2000

(51)Int.Cl.

H01S 5/30

(21)Application number : 10-190701

(71)Applicant : FUJI XEROX CO LTD

(22)Date of filing : 06.07.1998

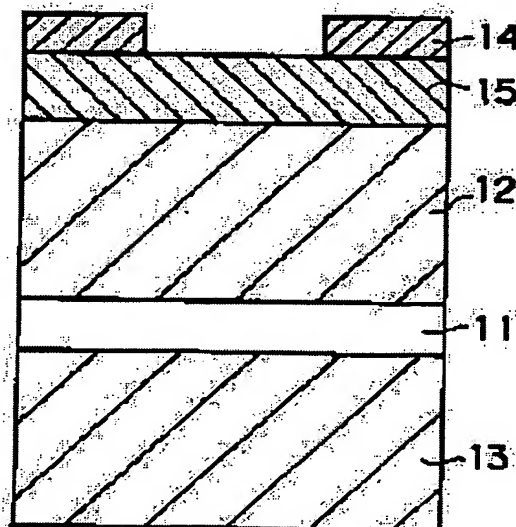
(72)Inventor : NAKAYAMA HIDEO  
SAKAMOTO AKIRA  
NAKAMURA TAKESHI  
KOYAMA FUMIO

### (54) SURFACE EMISSION LASER AND SURFACE EMISSION LASER ARRAY

#### (57)Abstract:

**PROBLEM TO BE SOLVED:** To provide a surface emission laser and a surface emission laser array having high brightness basic transverse mode optical output which can be manufactured easily with high reproducibility while suppressing positional fluctuation.

**SOLUTION:** A secondary resonator comprises an active layer region 11 including an active layer and upper and lower spacer layers laminated on the opposite sides thereof, an upper reflective layer 12 laminated on the upper spacer layer in the active layer region 11, a lower reflective layer 13 laminated on the lower spacer layer in the active layer region 11, and first and second adjusting layers 14, 15 formed on the periphery of laser light emitting region of the upper reflective layer 12.



#### LEGAL STATUS

[Date of request for examination]

07.11.2002

[Date of sending the examiner's decision of rejection]

**BEST AVAILABLE COPY**

[Kind of final disposal of application other than  
the examiner's decision of rejection or  
application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's  
decision of rejection]

[Date of requesting appeal against examiner's  
decision of rejection]

[Date of extinction of right]

Copyright (C); 1998,2003 Japan Patent Office

**\* NOTICES \***

JPO and NCIPi are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

**CLAIMS**

---

[Claim(s)]

[Claim 1] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the location which receives a laser beam before the outgoing radiation of a laser beam at least, and reflects a laser beam in said reflecting layer side, The surface emission-type laser characterized by the laser beam reflected in said reflecting layer and said 1st adjustment layer preparing the 2nd adjustment layer of the translucency by which incidence is carried out.

[Claim 2] Said 2nd adjustment layer is a surface emission-type laser according to claim 1 characterized by changing the phase of a laser beam reflected in said reflecting layer and said 1st adjustment layer.

[Claim 3] Said 2nd adjustment layer is a surface emission-type laser according to claim 1 characterized by carrying out the multiple echo of the laser beam which carried out incidence between said reflecting layers and said 1st adjustment layers.

[Claim 4] The thickness of said 2nd adjustment layer is the surface emission-type laser of the any 1 publication to claims 1-3 characterized by being the thickness which carries out laser oscillation by the basic transverse mode.

[Claim 5] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side, The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least. A laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer, and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out. The surface emission-type laser characterized by preparing the 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced.

[Claim 6] Said 2nd adjustment layer is a surface emission-type laser according to claim 5 characterized by changing the phase of a laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer, and attenuating the synthetic wave of the laser beam after a phase change, and the laser beam which carried out incidence.

[Claim 7] Said 2nd adjustment layer is a surface emission-type laser according to claim 5 characterized by being that to which interference by the multiple echo is generated and the reflection factor of the reflecting layer concerned is reduced by said 1st adjustment layer, 2nd adjustment layer concerned, and said reflecting layer.

[Claim 8] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side, The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least. A laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer, and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out. The surface emission-type laser characterized by preparing the 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced.

[Claim 9] For the oscillation wavelength of a laser beam [ in / for the oscillation wavelength of a laser beam / in / the phase of a laser beam reflected in one / said / at least / reflecting layer and said 1st adjustment layer is changed, and / the periphery based on / of said laser beam / outgoing radiation / the outgoing radiation core of said laser beam ], said 2nd adjustment layer is a surface emission-type laser according to claim 8 characterized by making it a different thing.

[Claim 10] Said 2nd adjustment layer is a surface emission-type laser according to claim 8 characterized by being that to which interference by the multiple echo is generated by said 1st adjustment layer, 2nd adjustment layer concerned, and said reflecting layer, and the effective refractive index in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

[Claim 11] Said 2nd adjustment layer is a surface emission-type laser according to claim 8 characterized by being that to which the effective refractive index in the periphery based on [ of a laser beam ] outgoing radiation is reduced while shifting the wavelength which resonates by said 1st adjustment layer, 2nd adjustment layer concerned, and said reflecting layer to a short wavelength side rather than the oscillation wavelength of a laser beam.

[Claim 12] The surface emission-type laser of the any 1 publication to claims 1-11 characterized by having differed in the part in which the optical thickness of said 2nd adjustment layer is located focusing on the outgoing radiation of a laser beam, and the part located in the periphery, and making high the reflection factor to the oscillation wavelength of the laser beam in the outgoing radiation core of a laser beam.

[Claim 13] The surface emission-type laser of the any 1 publication to claims 1-12 characterized by preparing the reflection property amendment layer which makes high the reflection factor to the oscillation wavelength of the laser beam in the outgoing radiation core of a laser beam in a part of part [ at least ] located focusing on the outgoing radiation of the laser beam in said 2nd adjustment layer.

[Claim 14] Said 2nd adjustment layer is the surface emission-type laser of the any 1 publication to claims 1-13 characterized by consisting of one kind or two kinds or more of ingredients, or a presentation.

[Claim 15] Said 1st adjustment layer is the surface emission-type laser of the any 1 publication to claims 1-14 characterized by consisting of one kind or two kinds or more of ingredients, or a presentation.

[Claim 16] Said 1st adjustment layer is the surface emission-type laser of the any 1 publication to claims 1-15 characterized by consisting of metals and making one electrode serve a double purpose.

[Claim 17] Said 1st adjustment layer is the surface emission-type laser of the any 1 publication to claims 1-15 characterized by consisting of semi-conductor multilayers.

[Claim 18] Said 1st adjustment layer is the surface emission-type laser of the any 1 publication to claims 1-15 characterized by consisting of dielectric multilayers.

[Claim 19] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser

beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out between one [ at least ] spacer layers and reflecting layers of an outside, and reflects a laser beam in one [ said / at least ] spacer layer side, Are a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and it is located between one [ said / at least ] reflecting layer and the 1st adjustment layer. The surface emission-type laser which incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out, and is characterized by preparing the 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced.

[Claim 20] Said 2nd adjustment layer is a surface emission-type laser according to claim 19 characterized by changing the phase of a laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer, and attenuating the synthetic wave of the laser beam after a phase change, and the laser beam which carried out incidence.

[Claim 21] Said 1st adjustment layer is a surface emission-type laser according to claim 19 characterized by making serve a double purpose and constituting said a part of reflecting layer.

[Claim 22] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out between one [ at least ] spacer layers and reflecting layers of an outside, and reflects a laser beam in one [ said / at least ] spacer layer side, Are a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out. The surface emission-type laser characterized by preparing the 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced.

[Claim 23] For the oscillation wavelength of a laser beam [ in / for the oscillation wavelength of a laser beam / in / the phase of a laser beam reflected in one / said / at least / reflecting layer and said 1st adjustment layer is changed, and / the periphery based on / of said laser beam / outgoing radiation / the outgoing radiation core of said laser beam ], said 2nd adjustment layer is a surface emission-type laser according to claim 22 characterized by making it a different thing.

[Claim 24] Said 1st adjustment layer is a surface emission-type laser according to claim 22 characterized by making serve a double purpose and constituting said a part of reflecting layer.

[Claim 25] The surface emission-type laser of the any 1 publication to claims 1-24 characterized by current constriction structure being a postmold.

[Claim 26] The surface emission-type laser of the any 1 publication to claims 1-24 characterized by current constriction structure being a selective oxidation mold.

[Claim 27] The surface emission-type laser of the any 1 publication to claims 1-24 characterized by current constriction structure being a proton placing mold.

[Claim 28] The field luminescence laser array characterized by coming to arrange two or more surface emission-type lasers of the any 1 publication to claims 1-27 in the shape of an array.

---

[Translation done.]

\* NOTICES \*

JPO and NCIPi are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

DETAILED DESCRIPTION

---

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the perpendicular resonator mold face luminescence laser and the field luminescence laser array which have a high brightness basic transverse-mode optical output especially about a surface emission-type laser and a field luminescence laser array.

[0002]

[Description of the Prior Art] Since, as for perpendicular resonator mold face luminescence laser (it is also called "VCSEL" Vertical Cavity Surface Emitting Laser and the following.), it has many advantages, like that a manufacturing cost is low compared with end-face luminescence mold laser, that the yield of manufacture is high, and two-dimensional-array-izing is easy, using it for the application of recent years many is examined. For example, Kenichi Iga, Fumio Koyama and Susumu Kinoshita, "Surface Emitting Semiconductor Lasers", IEEE Journal of Quantum The structure of VCSEL, the laser property, the application, etc. are explained to Electronics, 1988 and 24, and pp.1845-1855. In current, it has been improved greatly and the laser property has resulted in utilization in fields, such as optical communication. However, the conventional VCSEL still has a small basic transverse-mode optical output, and it is about at most 2-3mW, therefore the application is limited. If the basic transverse-mode optical output of VCSEL increases, for example, it is set to 5mW or more, it will become possible to use VCSEL for image write-in equipments, such as a laser beam printer, optical-magnetic disc equipment, etc.

[0003] As a technique for enlarging the basic transverse-mode optical output of VCSEL For example R. A.Morgan et al., "Transverse Mode Control of Vertical-Cavity Top-Surface-Emitting Lasers", and IEEE Photonics Technology Letters, 4, and pp.374- the VCSEL structure to which a basic transverse-mode optical output is made to increase is known by rationalizing the aperture of the outgoing radiation field of a laser beam as indicated by 377 and 1993.

[0004] As this VCSEL structure is called common proton in plastic mold and shown in drawing 16, on the n mold GaAs substrate which is not illustrated, the 28.5 period laminating of AlAs and the aluminum<sub>0.16</sub>Ga<sub>0.84</sub>As was carried out, and carrier concentration provides the lower n mold DBR (Distributed Bragg Reflector) layer 161 of 3x10<sup>18</sup>cm<sup>-3</sup>. On this lower n mold DBR layer 161, the undoping barrier layer field 162 containing a barrier layer and a SU \*\*-sir layer with quantum well structure is formed. On this barrier layer field 162, 20 period laminating of AlAs which inserts aluminum<sub>0.58</sub>Ga<sub>0.42</sub>As into an interface, and the aluminum<sub>0.16</sub>Ga<sub>0.84</sub>As was carried out, and carrier concentration has formed the up p mold DBR layer 163 of 3x10<sup>18</sup>cm<sup>-3</sup>-2x10<sup>19</sup>cm<sup>-3</sup>. Furthermore, the p lateral electrode 164 which carried out opening so that the aperture W of the outgoing radiation field 166 of a laser beam might serve as a predetermined value is formed in the upper part of the up p mold DBR layer 163. In order to limit the current impregnation field to a barrier layer, the high resistance field 165 formed by proton placing is established in the periphery of the up p mold DBR layer 163. In addition, n lateral electrode which is not illustrated is prepared in the lower part of the substrate which is not illustrated.

[0005] In VCSEL of the above structures, it is saying that a basic transverse-mode optical output can be made to increase by rationalizing the aperture W of current impregnation area size (path g) and the outgoing radiation field 166. However, it is difficult not to yet pass over the maximum of the basic transverse-mode optical output to 1.5mW, but to use it suitable for the application of optical-magnetic disc equipment etc. by such Koide force.

[0006] On the other hand, VCSEL which has a high brightness basic transverse-mode optical output is proposed by JP,10-56233,A. By this proposal, it has realized by controlling alternatively the laser oscillation conditions of the high order transverse mode of generating secondarily in addition to the basic transverse mode the high increase in power of a basic transverse-mode optical output. That is, the basic transverse-mode oscillation in VCSEL is produced at the core (approaching an optical axis) of optical waveguide, and since it is generated in the remote location estranged from the optical axis, a high order transverse-mode oscillation suppresses the shift to multimode oscillation, while optical loss of a resonator is increased gradually and it increases an inrush current value as the clearance from an optical axis increases, and enables the increment in a basic transverse-mode optical output.

[0007] When it explains concretely, as it is shown in drawing 17, this VCSEL The conductivity-type semi-conductor substrate 171, The up DBR layer 174 which has the conduction mode in which the lower DBR layer 172 and the lower DBR layer 172 are reverse, It is constituted by the barrier layer field 173 across which it faced between the lower DBR layer 172 and the up DBR layer 174, the low reflection factor zone 175 formed by ion implantation etc., the loss determiner 176, and electrodes 177 and 178, and outgoing radiation of the laser beam is carried out in accordance with an optical axis 179. The loss determiner 176 is processed into the concave configuration in order to increase optical loss of a resonator gradually according to the distance from an optical axis 179 increasing in the direction which intersects perpendicularly with an optical axis 179. The loss determiner 176 of this concave configuration has both the operation refracted in the laser beam of a resonator, and the operation which the side is made to diffuse the laser beam of a resonator, or shifts a focus.

[0008] Therefore, by this loss determiner 176, refraction loss increases according to the distance from the optical axis 179 in the direction which intersects perpendicularly with an optical axis 179 increasing, and optical loss of a resonator becomes large. On the other hand, the basic transverse-mode oscillation in this VCSEL approaches an optical axis 179, and is produced, and a high order transverse-mode oscillation is produced in the remote location estranged from the optical axis 179. Consequently, optical loss of a resonator will increase about the high order transverse mode, the threshold current density needed for initiation of the laser oscillation of the high order transverse mode will increase, and the maximum basic transverse-mode optical output will increase sharply.

[0009]

[Problem(s) to be Solved by the Invention] As mentioned above, according to the technique indicated by JP,10-56233,A, the high increase in power of the basic transverse mode becomes possible theoretically. However, it has problems, like it is remarkably difficult for coincidence to have a bad influence also on a basic transverse-mode property, and to form the loss determiner 176 of a predetermined configuration in stability.

[0010] namely, with the technique indicated by JP,10-56233,A It uses producing the basic transverse-mode oscillation in VCSEL at the core (approaching an optical axis) of optical waveguide, and producing a high order transverse-mode oscillation in the remote location estranged from the optical axis, as mentioned above. The reflection factor of a resonator was gradually decreased as it went on the outskirts from the center, namely, optical loss was increased gradually, and the laser oscillation of the high order transverse mode is controlled by that.

[0011] On the other hand, since the active region is small, generally as for VCSEL, a high reflection factor is needed for a resonator, as explained to Ken-ichi Iga and Fumio Koyama work "a surface emission-type laser" (Ohm-Sha, 1990). The resonator of VCSEL by which current research is done actually has 99% or more of reflection factor. On the contrary, if the reflection factor of a resonator is low, threshold current density will go up and laser oscillation will stop being able to happen easily.

[0012] However, with the technique indicated by JP,10-56233,A, it has the structure where the reflection



factor of a resonator falls from the optical axis 179 in the estranged location, and it not only controls the laser oscillation of the high order transverse mode, but the laser oscillation of the basic transverse mode is also controlled by coincidence, and there is a problem which cannot obtain sufficient high brightness basic transverse-mode optical output as a result.

[0013] Moreover, with the technique indicated by JP,10-56233,A, the loss determiner 176 is characterized by having the curved front face by considering as a concave configuration or considering as a convex configuration, as shown in drawing 17 . Therefore, the approach of producing the configuration of the loss determiner 176 is important, and is explained to JP,10-56233,A at the detail.

[0014] If the example is explained briefly, a photoresist 182 will be applied to the front face of the layer 181 which is going to form a curve front face as shown in drawing 18 (a). Next, as shown in drawing 18 (b), the cylindrical shape photoresist column 183 is formed using the usual exposure, development, and a BEKU process. If this photoresist column 183 is heated at the temperature of about 250-300 degrees C over about 5 - 20 minutes, as shown in drawing 18 R> 8 (c), it will deform into the layer 184 of the configuration which has a convex curve side. Even after returning this layer 184 to a room temperature, the configuration of that convex curve side is held to stability. Next, if dry etching is given using reactive ion etching (RIE) from the upper part, as a result of a layer's 184 acting as an etching mask and reflecting the configuration, as shown in drawing 18 (d), the structure 185 of having a convex curve side is formed.

[0015] As mentioned above, although how to form the structure of having a convex curve side was explained, if the photoresist column 183 is formed in the periphery on a layer 181 instead of a center section, the structure of having a concave curve side can be formed in the center section on a layer 181.

[0016] however, although it is needed for the configuration of the layer 184 which acts as an etching mask to have a predetermined curve side in a position, this curve side becomes always the same -- as -- repeatability -- good -- moreover, a location -- it is fairly difficult also by the current etching technique to form undependable. This problem becomes remarkable in preparing and forming many VCSEL components into a two-dimension array especially. Furthermore, in order to form the loss determiner 176 which has the configuration which has a predetermined curve side, and predetermined thickness, it is remarkably difficult to end etching in a suitable location after the disappearance time of the layer 184 which acts as an etching mask in a RIE process, or disappearance. moreover, the thing for which it controls etch selectivity with high precision between the ingredients which constitute the photoresist column 183 and the loss determiner 176 on the same substrate or a different substrate in preparing and forming many VCSEL components into a two-dimension array -- very much -- difficult -- therefore, every -- it is very difficult to arrange the reflection factor property of the loss determiner 176 between VCSEL components.

[0017] as mentioned above, the configuration and thickness of the loss determiner 176 -- every on the same substrate -- every between VCSEL components or on a different substrate -- every from which the lot of between VCSEL components or a process differs -- it is very difficult to abolish variation between VCSEL components, or to make variation small.

[0018] On the other hand, using the configuration of the concave curve side of the loss determiner 176, optical loss of a resonator is gradually increased as it estranges from an optical axis 179. Since an inrush current value is increased, the shift to the laser oscillation of the high order transverse mode is controlled and laser oscillation of the basic transverse mode is made possible by it If the configurations of the concave curve side of the loss determiner 176 differ, the optical output values of VCSEL which shift to the laser oscillation of the high order transverse mode, i.e., the maximum optical output value of the basic transverse mode, differ. consequently, every on the same substrate -- every between VCSEL components or on a different substrate -- every from which the lot of between VCSEL components or a process differs -- between VCSEL components -- every -- it is difficult to use industrially the technique indicated by JP,10-56233,A to the application as which the maximum optical output value of the basic transverse mode of a VCSEL component will differ, and a high brightness basic transverse-mode optical output is required.

[0019] Then, location variation is small, and is good, and the purpose of this invention has it in offering



the surface emission-type laser and field luminescence laser array which have a high brightness basic transverse-mode optical output easily producible moreover. [ of repeatability ]

[0020]

[Means for Solving the Problem] this invention person etc. came to complete header this invention for the above-mentioned technical problem being solvable with the following means, as a result of inquiring wholeheartedly. Namely, the surface emission-type laser of this invention is set to the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively. The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out to the location which receives a laser beam before the outgoing radiation of a laser beam at least, and reflects a laser beam in a reflecting layer side, The laser beam reflected in the reflecting layer and said 1st adjustment layer is characterized by preparing the 2nd adjustment layer of the translucency by which incidence is carried out.

[0021] In the surface emission-type laser to which an example of the surface emission-type laser of this invention comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ at least ] reflecting layer side, The outgoing radiation core of the laser beam generated in the barrier layer field is a periphery at least. A laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer, and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out. It is characterized by preparing the 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

[0022] In the surface emission-type laser to which other examples of the surface emission-type laser of this invention come to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ at least ] reflecting layer side, The outgoing radiation core of the laser beam generated in the barrier layer field is a periphery at least. A laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer, and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out. It is characterized by preparing the 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

[0023] In the surface emission-type laser to which other examples of the surface emission-type laser of this invention come to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out between one [ at least ] spacer layers and reflecting layers of an outside, and reflects a laser beam in one [ at least ] spacer layer side, Even if it is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation and is few It is located between one reflecting layer and the 1st adjustment layer. Incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out, and it is characterized by preparing the 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

[0024] In the surface emission-type laser to which other examples of the surface emission-type laser of this invention come to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out between one [ at least ] spacer layers and reflecting layers of an outside, and reflects a laser beam in one [ said / at least ] spacer layer side, Are a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out. It is characterized by preparing the 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

[0025] Moreover, the field luminescence laser array of this invention is characterized by coming to arrange two or more surface emission-type lasers of this invention in the shape of an array.

[0026] According to the surface emission-type laser of the above configurations, without spoiling the property of the laser oscillation of the basic transverse mode, the laser oscillation of the high order transverse mode generated secondarily can be controlled alternatively, and a basic transverse-mode optical output can be heightened. Furthermore, since the effective refractive index of the periphery based on [ of the laser beam in a laser cavity ] outgoing radiation becomes lower than the effective refractive index based on outgoing radiation, refractive-index waveguide structure can be formed in a laser cavity, and the laser oscillation of the basic transverse mode can be produced efficiently. Also structurally repeatability is high, a surface emission-type laser can be produced according to an easy process, it is a high yield and the surface emission-type laser from which a high brightness basic transverse-mode optical output is obtained can be offered cheaply.

[0027]

[Embodiment of the Invention] First, the principle of this invention is explained briefly. Drawing 1 (a) is the sectional view having simplified and shown the structure of the perpendicular resonator mold face luminescence laser (VCSEL) concerning this invention. The barrier layer field 11 which consists of the up spacer layer and lower spacer layer which carried out the laminating of this VCSEL to the both sides of a barrier layer and this barrier layer, The up reflecting layer 12 which carried out the laminating to the up spacer layer of the barrier layer field 11, and the lower reflecting layer 13 which carried out the laminating to the lower spacer layer of the barrier layer field 11, It is constituted by the secondary resonator which prepared and constituted the 1st adjustment layer 14 and the 2nd adjustment layer 15 in the periphery based on [ of the laser beam in the up reflecting layer 12 ] outgoing radiation. Moreover, in drawing 1 , since the 1st adjustment layer 14 does not have translucency, the outgoing radiation field of a laser beam is in agreement with the field surrounded in the 1st adjustment layer 14. In addition, in this specification, a laser beam uses the upper part explanation the side which carries out outgoing radiation for convenience, and uses the opposite side as the lower part. However, the upper part and the lower part are relative, and are not limited to this.

[0028] This secondary resonator is constituted by the up reflecting layer 12, the 1st adjustment layer 14, and the 2nd adjustment layer 15 of the translucency inserted among these, the laser beam generated in the barrier layer field passes the 2nd adjustment layer 15, and it is reflected in the 1st adjustment layer 14, and it is constituted so that it may be again reflected by the up reflecting layer 12 which counters the 1st adjustment layer 14 next and incidence may be carried out to the 2nd adjustment layer 15. A phase changes by carrying out incidence to the 2nd adjustment layer 15, the laser beam after a phase change and the laser beam which carried out incidence interfere in the laser beam which the multiple echo arose between the up reflecting layer 12 and the 1st adjustment layer 14 at this time, and was reflected between the up reflecting layer 12 and the 1st adjustment layer 14 mutually, and it attenuates that synthetic wave, and it is thought that a reflection factor falls. Moreover, when oscillation wavelength changes with change of a phase by the outgoing radiation field and periphery of a laser beam, it is thought that the optical confinement effectiveness arises. When it is made equal to the oscillation

wavelength (for example, 780nm) of the laser beam which oscillates the wavelength which resonates in a secondary resonator by controlling the optical thickness (thickness when amending the velocity of light with the dielectric constant of an ingredient) of the 2nd adjustment layer 15 by the basic transverse mode, the reflection factor of the secondary resonator in near the oscillation wavelength of a laser beam will decrease, consequently the reflection factor of the laser cavity in the periphery of the outgoing radiation field of a laser beam will fall locally.

[0029] Thus, if the reflection factor of the laser cavity in the periphery of the outgoing radiation field of a laser beam falls, as a broken line shows drawing 1 (b), the luminous intensity which carries out laser oscillation by the basic transverse mode becomes small in a periphery and a broken line shows drawing 1 (c), the luminous intensity which carries out laser oscillation will become small in a periphery by the high order transverse mode. Consequently, in order to concentrate on a periphery the light which carries out laser oscillation by the high order transverse mode to coming to concentrate the light which carries out laser oscillation by the basic transverse mode on an outgoing radiation field, the luminous intensity which carries out laser oscillation by the high order transverse mode every whenever it is reflected by the up reflecting layer 12 becomes low compared with the luminous intensity which carries out laser oscillation by the basic transverse mode.

[0030] For this reason, in order to obtain the luminous intensity needed in order to carry out laser oscillation by the high order transverse mode, it is necessary to pour a big current into a barrier layer from the conventional VCSEL which has not formed the secondary resonator. This can fully control the laser oscillation of the high order transverse mode, even if the threshold of the laser oscillation of the high order transverse mode means having become higher than before and makes the inrush current to a barrier layer larger than the conventional VCSEL, consequently it becomes possible [ carrying out laser oscillation only by the basic transverse mode ], even if it makes an inrush current larger than before, and the output of the laser beam of the basic transverse mode is high, and it can obtain the surface emission-type laser of high brightness. In addition, in drawing 1 (b) and (c), a continuous line expresses the luminous intensity which carries out laser oscillation with the luminous intensity which carries out laser oscillation by the basic transverse mode when not forming a respectively secondary resonator, and the high order transverse mode.

[0031] However, the reflection factor of the laser cavity in the periphery based on [ of a laser beam ] outgoing radiation should just fall with extent which the wavelength which resonates in a secondary resonator can fully control the laser oscillation in the high order transverse mode rather than needs to be not necessarily in agreement on the oscillation wavelength of a laser beam, and does not control the laser oscillation in the basic transverse mode too much.

[0032] Moreover, it is also possible to control the optical thickness of the 2nd adjustment layer 15, and to be able to make small the effective refractive index in the periphery to the effective refractive index in the outgoing radiation field of a laser beam, and for this to form refractive-index guided wave structure, if the wavelength which resonates in a secondary resonator is shifted to a short wavelength side rather than the oscillation wavelength (for example, 780nm) of a laser beam.

[0033] That is, when the resonant wavelength of a laser cavity shifts, it is known that the refractive index of the medium which constitutes a laser cavity will change effectually as indicated by Hadley (Optics Letters Vol.20, pp.1483-1485(1997).). According to it, the relation between change  $\Delta\lambda$  of the resonant wavelength of a laser cavity and effective-refractive-index change  $\Delta n$  of the medium which constitutes a laser cavity is  $\Delta\lambda/\lambda_0 = \Delta n/n_0$ . It becomes. However,  $\lambda_0$  The resonant wavelength of a laser cavity and  $n_0$  express the average refractive index of the medium which constitutes a resonator.

[0034] the resonant wavelength in the field where the 1st adjustment layer 14 and the 2nd adjustment layer 15 do not exist in the laser cavity which has a secondary resonator which was mentioned above as shown in drawing 2, i.e., the outgoing radiation field of a laser beam, --  $\lambda_0$  -- the resonant wavelength in the periphery of the field where the 1st adjustment layer 14 and the 2nd adjustment layer 15 exist if it carries out, i.e., the outgoing radiation core of a laser beam, --  $\lambda_1$  It shifts.

[0035] Thus, when resonant wavelength becomes a different thing for every field, in the field in which  $n_0$ , the 1st adjustment layer 14, and the 2nd adjustment layer 15 exist in the field in which the effective refractive index of a laser cavity also becomes a different thing in the outgoing radiation field and periphery of a laser beam, and the 1st adjustment layer 14 and the 2nd adjustment layer 15 do not exist from the above-mentioned relational expression, it is  $n_1$ . It becomes. Thus, it becomes possible by controlling the optical thickness of the 2nd adjustment layer 15 for resonant wavelength to become a different thing for every field, consequently to control the effective refractive index for every field.

[0036] Refractive-index waveguide structure can be formed by selecting the optical thickness of the 2nd adjustment layer 15 to the effective refractive index of the outgoing radiation field of a laser beam, using such a property, so that the effective refractive index of the periphery may become small. Furthermore, refractive-index waveguide structure with a good basic transverse-mode laser oscillation property can be formed by also taking into consideration the basic transverse mode of refractive-index waveguide, the distribution conditions of the photoelectrical place of the high order transverse mode, and the reflection factor difference of an outgoing radiation field and its periphery, and selecting the optical thickness of the 2nd adjustment layer 15. In addition, although the case where the effective refractive index of the periphery was made small to an outgoing radiation field so far was shown, the effective refractive index of a periphery is made high and you may make it form refractive-index anti-waveguide structure in the reverse. However, it is obtained that a property [ make / the reflection factor and effective refractive index of a periphery / smaller than both outgoing radiation fields ] is more desirable. That is, the effective refractive index of an outgoing radiation field and its periphery is changed by forming a secondary resonator, and it becomes possible to form optical confinement structure.

[0037] In addition, conductive ingredients, such as a metal, can constitute the 1st adjustment layer 14 above, this can also be made to serve a double purpose as an electrode, and lamination can be simplified in this case. Since decline in a reflection factor and change of an effective refractive index arise in the part which has the 1st adjustment layer also in this case although a laser beam may carry out outgoing radiation to the 1st adjustment layer from a part when it has a certain amount of [ the 1st adjustment layer ] translucency, although the case where it was in agreement with the field where the outgoing radiation field of a laser beam was surrounded by the 1st adjustment layer so far was explained, the laser oscillation in the basic transverse mode occurs. That is, the 1st adjustment layer is a periphery based on [ of a laser beam ] outgoing radiation (part where laser beam intensity distribution serve as max), and before the laser beam generated in the barrier layer field carries out outgoing radiation of the operation of this invention to the exterior of a laser component as an output light, it is done so by being arranged in the location which receives this laser beam. Moreover, the 1st adjustment layer is arranged so that laser oscillation may be carried out by the basic transverse mode, may be prepared over the perimeter enclosure based on outgoing radiation, or may be divided and constituted in plurality so that an outgoing radiation core may be removed. However, it is better to have arranged at least the part so that it may see from [ of laser ] outgoing radiation and may lap with the field to which the laser drive current to a barrier layer is poured in, in order to reflect efficiently the laser beam generated in the barrier layer field. Moreover, a reflecting layer and the 1st adjustment layer reflect, and the 2nd adjustment layer should just have translucency in extent which the laser beam which carried out incidence interferes mutually, and suits.

[0038] [Gestalt of the 1st operation] Drawing 3 is the sectional view of the perpendicular resonator mold face luminescence laser (VCSEL) concerning the gestalt of operation of the 1st of this invention. The barrier layer field 11 which consists of the up spacer layer and lower spacer layer which carried out the laminating of this VCSEL to the both sides of a barrier layer and this barrier layer, The up reflecting layer 12 which carried out the laminating to the up spacer layer of this barrier layer field 11, It is constituted by the lower reflecting layer 13 which carried out the laminating to the lower spacer layer of the barrier layer field 11, and the secondary resonator which prepared and constituted the 1st adjustment layer 14 and the 2nd adjustment layer 15 in the periphery based on [ of the laser beam in the up reflecting layer 12 ] outgoing radiation.

[0039] The lower SU \*\*-sir layer which the barrier layer field 11 becomes from undoping aluminum0.5

Ga<sub>0.5</sub>As, An undoping quantum well barrier layer (it consists of three layers of aluminum<sub>0.11</sub>Ga<sub>0.89</sub>As quantum well layers of 90nm of thickness, and four layers of aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As barrier layers of 50nm of thickness), It consists of aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As up SU<sup>\*\*-</sup>ir layers of undoping, and the optical thickness of this barrier layer field 11 serves as wavelength in a medium (for example, 780nm).

[0040] The up reflecting layer 12 consists of DBR (multiplex Bragg diffraction mirror) which carried out 20 period laminating by turns, and constituted aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As so that each optical thickness might serve as quarter-wave length to laser oscillation wavelength (for example, 780nm).

[0041] the optical thickness which carried out the laminating of the 2nd adjustment layer 15 all over the whole surface of the up reflecting layer 12, i.e., the outgoing radiation core of a laser beam, and its periphery -- laser oscillation wavelength (for example, 780nm) -- receiving -- 1.55/-- it consists of 1.6/4 time as many aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As as this preferably four to 1.62/4 time.

[0042] The 1st adjustment layer 14 is constituted by gold of 200nm of thickness which carried out the laminating to the periphery based on [ of the laser beam on the 2nd adjustment layer 15 ] outgoing radiation. Here, although thickness of the 1st adjustment layer 14 was set to 200nm, if there is thickness about 100nm or more, the effectiveness which controls the oscillation of the high order transverse mode will fully be acquired.

[0043] The lower reflecting layer 13 consists of DBR (multiplex Bragg diffraction mirror) which carried out the 40.5 period laminating by turns, and constituted aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As so that each optical thickness might serve as quarter-wave length to laser oscillation wavelength (for example, 780nm). In addition, the laminating of the lower reflecting layer 13 is carried out on the substrate which is not illustrated through the buffer layer which is not illustrated.

[0044] The secondary resonator of this example is constituted by the up reflecting layer 12, the 1st adjustment layer 14, and the 2nd adjustment layer 15 pinched among these, changes the phase of a laser beam by the multiple echo between the up reflecting layer 12 and the 1st adjustment layer 14, generates interference of a light wave, and reduces the reflection factor in the periphery based on [ of a laser beam ] outgoing radiation.

[0045] Drawing 4 is a graph which shows the relation between the optical thickness of the 2nd adjustment layer 15, and the amplitude reflectance in the laser oscillation wavelength of 780nm. The continuous line in drawing 4 shows change of the amplitude reflectance in the laser oscillation wavelength of 780nm in the periphery based on [ that the 1st adjustment layer 14 and the 2nd adjustment layer 15 when changing the optical thickness of the 2nd adjustment layer 15 exist / of a laser beam ] outgoing radiation. When the optical thickness of the 2nd adjustment layer 15 is abbreviation 1.6x quarter-wave length so that the continuous line of drawing 4 may show, an amplitude reflectance serves as about 0.385 and min.

[0046] On the other hand, the broken line in drawing 4 shows change of the amplitude reflectance in the laser oscillation wavelength of 780nm in the periphery based on [ that the 2nd adjustment layer 15 when changing the optical thickness of the 2nd adjustment layer 15 exists / of a laser beam ] outgoing radiation in VCSEL which the 1st adjustment layer 14 was not formed, and also was constituted like drawing 3 . Also when the optical thickness of the 2nd adjustment layer 15 is abbreviation 1.6x quarter-wave length so that the broken line of drawing 4 may show, an amplitude reflectance maintains about 0.992 and a high condition.

[0047] Drawing 5 is a graph which shows a reflectance spectrum on the strength in case the optical thickness of the 2nd adjustment layer 15 is abbreviation 1.6x quarter-wave length. Drawing 5 (a) is a reflectance spectrum on the strength at the time of forming the 1st adjustment layer 14, and drawing 5 (b) is a reflectance spectrum on the strength at the time of not forming the 1st adjustment layer 14. As shown in drawing 5 (a), in the reflectance spectrum of the up reflecting layer 12 in the periphery based on [ that the 1st adjustment layer 14 and the 2nd adjustment layer 15 exist / of a laser beam ] outgoing radiation, depression of a reflection factor appears near the laser oscillation wavelength of 780nm according to the fall effectiveness of the reflection factor by the secondary resonator, and/or an effective

refractive index. On the other hand, as shown in drawing 5 (b), when the 1st adjustment layer 14 is not formed, to the reflectance spectrum of the up reflecting layer 12 in the periphery based on [ that the 2nd adjustment layer 15 exists / of a laser beam ] outgoing radiation, near, it is not generated near the laser oscillation wavelength of 780nm, but depression of a reflection factor is maintaining the condition that a reflection factor is still high.

[0048] If such a property is used, it will become possible to consider as the configuration which carries out the laminating of the 2nd adjustment layer 15 all over the up reflecting layer 12 (an outgoing radiation core and whole surface of the periphery), and carries out the laminating of the 1st adjustment layer 14 to the periphery of the 2nd adjustment layer 15 further, and the profits from which a manufacture process becomes simple will be obtained as compared with the case where the 2nd adjustment layer 15 is formed only in the periphery of the up reflecting layer 12.

[0049] Moreover, [ whether the wavelength which controls the optical thickness of the 2nd adjustment layer 15, and resonates in a secondary resonator is shifted to a short wavelength side rather than the oscillation wavelength (for example, 780nm) of a laser beam, and ] Or by shifting the wavelength which resonates at the outgoing radiation core of a laser beam to a long wavelength side, to the effective refractive index in the outgoing radiation core of a laser beam, the effective refractive index in the periphery can be made small, and this becomes possible [ forming refractive-index guided wave structure ].

[0050] Furthermore, refractive-index waveguide structure with a good basic transverse-mode laser oscillation property can be formed by also taking into consideration the basic transverse mode of refractive-index waveguide, the distribution conditions of the photoelectrical place of the high order transverse mode, and the reflection factor difference of an outgoing radiation core and its periphery, and selecting the optical thickness of the 2nd adjustment layer 15.

[0051] [Gestalt of the 2nd operation] Drawing 6 (a) and (b) are the sectional views of the perpendicular resonator mold face luminescence laser (VCSEL) applied to the gestalt of operation of the 2nd of this invention, respectively. In VCSEL shown in drawing 3, drawing 6 (a) considered as the gestalt which removed the part located on the outgoing radiation core of a laser beam among the 2nd adjustment layers 15 which carried out the laminating to the up reflecting layer 12, and also is the same configuration. In VCSEL shown in drawing 3, drawing 6 (b) carried out the laminating of the reflection property amendment layer 16 for raising the reflection factor to the oscillation wavelength (for example, 780nm) of a laser beam further on the outgoing radiation core of the laser beam in the 2nd adjustment layer 15, and also is the same configuration. The reflection property amendment layer 16 can consist of dielectrics, such as a silicon dioxide, etc. Each example of a configuration shown in drawing 6 (a) and (b) improves a reflection property so that the reflection factor in the outgoing radiation core of a laser beam may become high.

[0052] Drawing 7 is a graph which shows the reflectance spectrum of the up reflecting layer 12 on the strength. The continuous line in drawing 7 shows the reflectance spectrum of the up reflecting layer 12 at the time of not forming the 1st adjustment layer 14 and the 2nd adjustment layer 15 in drawing 6 (a) and the example of a configuration of (b) on the strength. The broken line in drawing 7 is the same spectrum Fig. as drawing 5 (b) showing the reflectance spectrum of the up reflecting layer 12 at the time of not forming the 1st adjustment layer 14 and the reflection property amendment layer 16 in the example of a configuration of drawing 6 (b) on the strength. Moreover, the oscillation wavelength of a laser beam expands the reflectance spectrum on the strength in near 780nm to the interior of the graph of drawing 7, and is shown in it.

[0053] The reflection factor of the up reflecting layer 12 in near the oscillation wavelength of 780nm of a laser beam on the strength becomes higher than the case where the direction at the time of not carrying out the laminating of the 2nd adjustment layer 15 carries out the laminating of the 2nd adjustment layer 15 so that drawing 7 may show. This means that the 2nd adjustment layer 15 is reducing the reflection property of the up reflecting layer 12.

[0054] Therefore, as shown in drawing 6 (a), the reflection factor of the up reflecting layer 12 in the configuration which removes the part on the outgoing radiation core of the laser beam in the 2nd



adjustment layer 15, then the outgoing radiation core of a laser beam can be made higher. Moreover, as shown in drawing 6 (b), the reflection factor of the up reflecting layer 12 in the outgoing radiation core of a laser beam can be made higher by carrying out the laminating of the reflection property amendment layer 16 to the part on the outgoing radiation core of the laser beam in the 2nd adjustment layer 15 further.

[0055] Moreover, [ whether the wavelength which controls the optical thickness of the 2nd adjustment layer 15, and resonates in a secondary resonator is shifted to a short wavelength side rather than the oscillation wavelength (for example, 780nm) of a laser beam, and ] Or by shifting the wavelength which resonates at the outgoing radiation core of a laser beam to a long wavelength side, to the effective refractive index in the outgoing radiation core of a laser beam, the effective refractive index in the periphery can be made small, and this becomes possible [ forming refractive-index guided wave structure ].

[0056] Furthermore, refractive-index waveguide structure with a good basic transverse-mode laser oscillation property can be formed by also taking into consideration the basic transverse mode of refractive-index waveguide, the distribution conditions of the photoelectrical place of the high order transverse mode, and the reflection factor difference of an outgoing radiation core and its periphery, and selecting the optical thickness of the 2nd adjustment layer 15.

[0057] [Gestalt of the 3rd operation] Drawing 8 is the sectional view of the perpendicular resonator mold face luminescence laser (VCSEL) concerning the gestalt of operation of the 3rd of this invention. In VCSEL shown in drawing 3, consider this example as the configuration which consists of two or more layers, without considering the 2nd adjustment layer 15 as the presentation of homogeneity, and it made the 1st adjustment layer 14 serve a double purpose as an electrode, and also it is the same configuration. The 1st adjustment layer 14 is formed with gold of 200nm of thickness, and this is made to serve a double purpose as one electrode for pouring a current into VCSEL. GaAs contact layer of 20nm of thickness for 2nd adjustment layer 15 to make good electric junction in 1st adjustment layer 14 and semi-conductor layer which are made to serve a double purpose as electrode 15A, Optical thickness receives laser oscillation wavelength (780nm). aluminum<sub>0.3</sub> Ga<sub>0.7</sub> As layer 15B of abbreviation 0.44x quarter-wave length, Optical thickness is constituted to laser oscillation wavelength (780nm) by three layers with aluminum<sub>0.9</sub> Ga<sub>0.1</sub> As layer 15C of quarter-wave length.

[0058] Thus, by considering the 2nd adjustment layer 15 as the configuration set to contact layer 15A and aluminum<sub>0.3</sub> Ga<sub>0.7</sub> As layer 15B from two or more presentations of aluminum<sub>0.9</sub> Ga<sub>0.1</sub> As layer 15C Fully taking electric junction in the 1st adjustment layer 14 which makes an electrode serve a double purpose, it can be set to about 0.705 by the periphery based on [ of a laser beam ] outgoing radiation, it is set to about 0.993 focusing on outgoing radiation, and the amplitude reflectance in the oscillation wavelength of 780nm of a laser beam can obtain the laser output of the high brightness basic transverse mode.

[0059] As mentioned above, the configuration of the 2nd adjustment layer 15 is not restricted to the configuration which consists of a single ingredient, but if it can constitute the secondary resonator which can control the laser oscillation of the high order transverse mode appropriately, it can also be considered as the multilayer configuration which consists of two or more ingredients.

[0060] Moreover, [ whether the wavelength which controls the optical thickness of the 2nd adjustment layer 15, and resonates in a secondary resonator is shifted to a short wavelength side rather than the oscillation wavelength (for example, 780nm) of a laser beam, and ] Or by shifting the wavelength which resonates at the outgoing radiation core of a laser beam to a long wavelength side, to the effective refractive index in the outgoing radiation core of a laser beam, the effective refractive index in the periphery can be made small, and this becomes possible [ forming refractive-index guided wave structure ].

[0061] Furthermore, refractive-index waveguide structure with a good basic transverse-mode laser oscillation property can be formed by also taking into consideration the basic transverse mode of refractive-index waveguide, the distribution conditions of the photoelectrical place of the high order transverse mode, and the reflection factor difference of an outgoing radiation core and its periphery, and



selecting the optical thickness of the 2nd adjustment layer 15.

[0062] [Gestalt of the 4th operation] Although mentioned later for details, in this invention, it is good also as a configuration which inserts in a part of periphery based on [ of the laser beam in an up DBR layer ] outgoing radiation the 2nd adjustment layer from which optical thickness is set to one fourth of the wavelength in a medium, and prepares the 1st adjustment layer in it between this 2nd adjustment layer and the spacer layer of a barrier layer field. The reflection factor and/or effective refractive index of a laser cavity in the part can be reduced by the 1st adjustment layer located also by such configuration between the 2nd adjustment layer in an up DBR layer, and the spacer layer of a barrier layer field. However, when the 2nd adjustment layer is inserted in right above [ of the spacer layer of a barrier layer field ]; the effectiveness of reducing the reflection factor and/or effective refractive index of a laser cavity in the part is not fully acquired. Moreover, it is good also as a configuration which makes a part of up DBR layer serve a double purpose for the 1st adjustment layer.

[0063] [the gestalt of the 5th operation] -- although mentioned later for details -- this invention -- setting -- the plurality of VCSEL -- the same substrate top -- or it may arrange on a different substrate and a VCSEL array may be constituted.

[0064] As mentioned above, although the gestalt of operation of this invention was explained As an ingredient which faces carrying out this invention and constitutes the 2nd adjustment layer 15 What is necessary is just to use a semi-conductor and a dielectric, when adopting the configuration in which the 2nd adjustment layer 15 does not serve as a path which pours a current into a barrier layer that what is necessary is just to use a conductive ingredient especially when adopting the configuration used as the path where it is not limited, for example, the 2nd adjustment layer 15 pours a current into a barrier layer. Moreover, that what is necessary is just to use conductive ingredients, such as gold, when it is not limited especially, for example, an electrode is made to serve a double purpose also about the ingredient which constitutes the 1st adjustment layer 14, when not making an electrode serve a double purpose, a semi-conductor and a dielectric can be used. Moreover, you may be the configuration which consists of a single ingredient, and may be the multilayer configuration which consists of two or more ingredients. Moreover, it is not limited to dielectrics, such as a silicon dioxide, and the ingredient which constitutes the reflection property amendment layer 16 may also constitute from other dielectrics and semi-conductor metallurgy groups.

[0065]

[Example] Hereafter, the example of this invention is explained.

[0066] [Example 1] This example 1 is the thing corresponding to the gestalt of the 1st operation shown in drawing 3 . it is shown in drawing 9 (a) -- as -- organic metal vapor growth (MOCVD) -- carrier concentration carries out the laminating of the n mold GaAs buffer layer 92 whose thickness is about 0.2 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$  on the n mold GaAs substrate 91 by law.

[0067] this buffer layer 92 top -- MOCVD -- by law, the 40.5 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is carried out by turns so that each optical thickness may be set to one fourth of the wavelength in a medium, and carrier concentration forms [ the total thickness ] the lower n mold DBR layer 93 which is about 4 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$ .

[0068] this lower n mold DBR layer 93 top -- MOCVD -- with an undoping lower aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As SU \*\*-sir layer by law Undoping quantum well barrier layer (with three layers of aluminum<sub>0.11</sub>Ga<sub>0.89</sub>As quantum well layers of 90nm of thickness) The optical thickness constituted by the undoping up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As SU \*\*-sir layer as consisting of four layers of aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As barrier layers of 50nm of thickness forms the barrier layer field 94 used as the wavelength in a medium.

[0069] this barrier layer field 94 top -- MOCVD -- by law, 20 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is carried out by turns so that each optical thickness may be set to one fourth of the wavelength in a medium, and carrier concentration forms [ the total thickness ] the up p mold DBR layer 95 which is about 2 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$ .

[0070] the besides section p mold DBR layer 95 top -- MOCVD -- law -- carrier concentration --  $1 \times 10^{18} \text{cm}^{-3}$  -- optical thickness --  $1.55/\text{of the wavelength in a medium}$  -- the laminating of the  $1.6/4$

time as many 2nd adjustment layer 96 of p mold aluminum<sub>0.3</sub> Ga<sub>0.7</sub> As as this is carried out preferably four to 1.62/4 time.

[0071] Here, although not illustrated, carrier concentration may carry out the laminating of the p mold GaAs contact layer whose optical thickness is about 10nm to the topmost part by  $1 \times 10^{19} \text{cm}^{-3}$ .

Moreover, although not stated in detail, in order to lower electric resistance of the DBR layers 93 and 95, the optical thickness which changed [% / 30 ] the AlAs presentation from 90% to the interface of aluminum<sub>0.9</sub> Ga<sub>0.1</sub> As and aluminum<sub>0.3</sub> Ga<sub>0.7</sub> As gradually may prepare the field which is about 9nm.

[0072] Here, in membrane formation by the MOCVD method, the silane was used for p molds cyclo pen TAJINIUMU magnesium and for n molds as a dopant ingredient, using trimethylgallium, trimethylaluminum, and an arsine as material gas, and substrate temperature at the time of film growth was made into 750 degrees C, carried out sequential change of the material gas, and formed membranes continuously.

[0073] Then, as shown in drawing 9 (b), the resist mask R is formed on a crystal growth layer with photolithography, by reactive ion etching using the carbon tetrachloride as etching gas, it etches to the middle of the lower n mold DBR layer 93, the post S which consists of the cylinder or prism whose path is about 10-30 micrometers is formed, and this forms the current narrow segment.

[0074] After removing Resist R, as it is shown in drawing 9 (c), after vapor-depositing the SiN layer 97 on the 2nd adjustment layer 96 using plasma-CVD equipment, the SiN layer 97 located in the upper part of Post S is exfoliated by etching of SiN using a usual photolithography process and buffered fluoric acid.

[0075] Then, as shown in drawing 9 (d), using a photolithography process, a resist pattern T is formed in the up center section of the post S, and Ti and Au which will constitute the 1st adjustment layer which makes p lateral electrode serve a double purpose from the upper part using EB vacuum evaporation machine are vapor-deposited by the thickness of 10nm and 200nm, respectively.

[0076] As an acetone is used, it exfoliates with Ti and Au which were vapor-deposited by the upper part and a resist pattern T is finally shown in drawing 9 (e), VCSEL of the structure where the laminating of the 1st adjustment layer 98 which makes p lateral electrode serve a double purpose was carried out to the periphery based on [ of the laser beam in the 2nd adjustment layer 96 ] outgoing radiation is obtained.

[0077] In this VCSEL, although outgoing radiation of the laser beam is carried out from the center section of the post S which is the field where the 2nd adjustment layer 96 which makes p lateral electrode serve a double purpose does not exist, i.e., the field where the resist pattern T existed, the aperture of this outgoing radiation field has desirable about 3-20 micrometers. In addition, AuGe is vapor-deposited by the rear face of a substrate 91 as an n lateral electrode which is not illustrated.

[0078] VCSEL produced as mentioned above was able to set, and the resonator reflection factor in directly under [ based on / of the laser beam of the center section of the post S / outgoing radiation ] was as high as about 99.5%, and the resonator reflection factor in directly under [ of the 1st adjustment layer 98 which makes p lateral electrode serve a double purpose ] was able to become low like the result shown in drawing 4 , and was able to control the laser oscillation of the high order transverse mode appropriately. Consequently, in order to obtain the laser oscillation of the basic transverse mode in a Prior art, although to be referred to as 5 micrometers or less was needed, according to this invention, the laser oscillation of the basic transverse mode of the aperture of the outgoing radiation field of a laser beam becomes possible also as 5 micrometers or more about the aperture of an outgoing radiation field, and it can obtain a high brightness basic transverse-mode optical output.

[0079] When the laser oscillation of the basic transverse mode of VCSEL concerning this example 1 and the laser oscillation of the high order transverse mode, the laser oscillation of the basic transverse mode of the conventional VCSEL shown in drawing 17 , and the laser oscillation of the high order transverse mode were investigated, the result shown in drawing 10 was obtained. That is, although the laser oscillation of the high order transverse mode is controlled and only the basic transverse mode oscillates VCSEL and the conventional VCSEL concerning an example 1 when the inrush current to a barrier layer is made to increase, compared with VCSEL of an example 1, it turns out by the conventional

VCSEL that both the thresholds and effectiveness of a current that start the laser oscillation of the basic transverse mode are falling.

[0080] Although constituted using aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As, the 2nd adjustment layer 96 can also consist of this example 1 using other ingredients, if it is the ingredient into which the reflection factor and/or effective refractive index of a laser cavity in directly under [ of the 1st adjustment layer 98 ] can be reduced. However, like this example 1, when the 2nd adjustment layer 96 constitutes the path of an inrush current, it is a conductivity-type ingredient and it is desirable to use an ingredient with easy impregnation of a current.

[0081] Moreover, although it etches to the middle of the lower n mold DBR layer 93 and Post S is formed in this example 1, from an up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As SU \*\*-sir layer or it, etching may be suspended in the upper part, Post S may be formed, and it may etch to right above [ of a substrate 91 ], and Post S may be formed.

[0082] Moreover, although AlGaAs was used as an ingredient of a barrier layer, VCSEL for near-infrared can also be constituted using GaAs or InGaAs, and VCSEL for red can also consist of this example 1 using InGaP or AlGaInP. Furthermore, VCSEL for 1.3-1.5-micrometer bands can also be constituted using a VCSEL and InGaAsP system etc. for blue or ultraviolet rays using a GaN system, a ZnSe system, etc.

[0083] Moreover, an insulator layer can also be used by not being limited to a semiconductor material and choosing various current impregnation methods as an ingredient of the DBR layers 93 and 95. When using an insulator layer as an ingredient of the DBR layers 93 and 95, it is desirable to use an insulator layer rather than a semi-conductor also as an ingredient of the 2nd adjustment layer 96.

[0084] [Example 2] This example 2 is the thing corresponding to the gestalt of the 2nd operation shown in drawing 6 (a). it is shown in drawing 11 R> 1 -- as -- MOCVD -- carrier concentration carries out the laminating of the n mold GaAs buffer layer 92 whose thickness is about 0.2 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$  on the n mold GaAs substrate 91 by law.

[0085] this buffer layer 92 top -- MOCVD -- by law, the 40.5 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is carried out by turns so that each optical thickness may be set to one fourth of the wavelength in a medium, and carrier concentration forms [ the total thickness ] the lower n mold DBR layer 93 which is about 4 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$ .

[0086] this lower n mold DBR layer 93 top -- MOCVD -- with an undoping lower aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As SU \*\*-sir layer by law Undoping quantum well barrier layer (with three layers of aluminum<sub>0.1</sub>Ga<sub>0.89</sub>As quantum well layers of 90nm of thickness) The optical thickness which consisted of undoping up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As SU \*\*-sir layers as consisting of four layers of aluminum<sub>0.3</sub>Ga<sub>0.1</sub>As barrier layers of 50nm of thickness forms the barrier layer field 94 used as the wavelength in a medium.

[0087] this barrier layer field 94 top -- MOCVD -- carrier concentration forms the p mold AlAs layer 99 from which optical thickness is set to one fourth of the wavelength in a medium by  $1 \times 10^{18} \text{cm}^{-3}$  by law. On this p mold AlAs layer 99, the 19.5 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is carried out by turns so that each optical thickness may be set to one fourth of the wavelength in a medium, and carrier concentration forms [ the total thickness ] the up p mold DBR layer 95 which is about 2 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$ .

[0088] the besides section p mold DBR layer 95 top -- MOCVD -- law -- carrier concentration --  $1 \times 10^{18} \text{cm}^{-3}$  -- optical thickness -- 1.55/of the wavelength in a medium -- the 1.6/4 time as many p mold In<sub>0.5</sub>Ga<sub>0.5</sub>P 2nd adjustment layer 96 as this is formed preferably four to 1.62/4 time.

[0089] Here, although not illustrated, carrier concentration may carry out the laminating of the p mold GaAs contact layer whose optical thickness is about 10nm to the topmost part by  $1 \times 10^{19} \text{cm}^{-3}$ . Moreover, although not stated in detail, in order to lower electric resistance of the DBR layers 93 and 95, the optical thickness which changed [ % / 30 ] the AlAs presentation from 90% to the interface of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and aluminum<sub>0.3</sub>Ga<sub>0.1</sub>As gradually may prepare the field which is about 9nm.

[0090] Here, in membrane formation by the MOCVD method, as a dopant ingredient, the silane was

used for p molds cyclo pen TAJINIUMU magnesium and for n molds, using trimethylgallium, trimethylaluminum, trimethylindium, an arsine, and phosphoretted hydrogen as material gas, and without having considered as 750 degrees C and breaking a vacuum, the substrate temperature at the time of film growth carried out sequential change of the material gas, and formed membranes continuously.

[0091] next, a path is about 30 micrometers like an example 1 -- the post S of the shape of cylindrical or a pyramid is formed. Then, oxidize from the side, only the AlAs layer 99 is made to form into high resistance with a steam all over about 400-degree C furnace, and this forms the current narrow segment. Although a non-oxidizing field turns into a current impregnation field to a barrier layer at this time, that path is about 3-20 micrometers.

[0092] Next, the SiN layer (insulator layer) 97 and the 1st adjustment layer 98 which makes p lateral electrode serve a double purpose are formed like an example 1. Then, VCSEL of the structure where the laminating of the 1st adjustment layer 98 and the 2nd adjustment layer 96 which make p lateral electrode serve a double purpose in the periphery based on [ of a laser beam ] outgoing radiation by the wet etching by the usual photolithography process and the etchant which consisted of phosphoric acid, a hydrochloric acid, and water as the part located in the up center section of the post S among the In<sub>0.5</sub>Ga<sub>0.5</sub>P 2nd adjustment layers 96 is deleted and it was shown in drawing 11 was carried out is obtained.

[0093] As the gestalt of the 2nd operation also explained, VCSEL concerning this example 2 can control the laser oscillation of the high order transverse mode, and can obtain the laser oscillation of the high brightness basic transverse mode.

[0094] Moreover, in this example 2, although the part in the up center section of the post S is deleted among the 2nd adjustment layers 96, as the gestalt of the 2nd operation also explained, even if it carries out the laminating of the reflection property amendment layer on the 2nd adjustment layer 96 in the up center section of the post S instead of deleting, the same effectiveness can be acquired.

[0095] Moreover, like an example 1, although the In<sub>0.5</sub>Ga<sub>0.5</sub>P layer which can do selective etching easily was used as an ingredient of the 2nd adjustment layer 96 in this example 2, if the reflection factor and/or effective refractive index of a laser cavity in the periphery based on [ of a laser beam ] outgoing radiation can be reduced, other ingredients can also be used.

[0096] Moreover, also in this example 2, like an example 1, although AlGaAs was used as an ingredient of a barrier layer, VCSEL for near-infrared can also be constituted using GaAs or InGaAs, and VCSEL for red can also be constituted using InGaP or AlGaInP. Furthermore, VCSEL for 1.3-1.5-micrometer bands can also be constituted using a VCSEL and InGaAsP system etc. for blue or ultraviolet rays using a GaN system, a ZnSe system, etc.

[0097] [Example 3] This example 3 is the thing corresponding to the gestalt of the 3rd operation shown in drawing 8. As shown in drawing 12, on the up DBR layer 95, the 2nd adjustment layer 96 which consisted of three layers is formed. Namely, p mold aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As layer 96C from which optical thickness is set to one fourth of the wavelength in a medium by  $1 \times 10^{18} \text{cm}^{-3}$  by the carrier concentration which formed this 2nd adjustment layer 96 on the up DBR layer 95, p mold aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As layer 96B from which optical thickness becomes [ the carrier concentration prepared on this layer 96C ]  $0.44 \times 10^{19}$  of the wavelength in a medium / 4 times by  $1 \times 10^{18} \text{cm}^{-3}$ , The carrier concentration prepared on this layer 96B consists of p mold GaAs contact layer 96A whose optical thickness is 20nm by  $1 \times 10^{19} \text{cm}^{-3}$ .

[0098] Moreover, in this example 3, a proton is driven into the flank of the up DBR layer 95, the high resistance field 100 is formed, without forming post S like an example 1, and this forms the current narrow segment.

[0099] Moreover, the 1st adjustment layer 98 which vapor-deposits Ti and Au and makes p lateral electrode serve a double purpose like an example 1 is formed in the periphery on the 2nd adjustment layer 96. Center-section opening of this 1st adjustment layer 98 serves as an outgoing radiation field of a laser beam.

[0100] As for the core of the outgoing radiation field of a laser beam, and the core of the current narrow

segment which drove in and formed the proton, it is desirable that it is in agreement with the optical axis of a laser beam as much as possible. In addition, other configurations are the same as that of an example 1, and the explanation is omitted.

[0101] VCSEL produced as mentioned above was able to set, and the resonator reflection factor in directly under [ based on / of the laser beam of a center section / outgoing radiation ] was as high as about 99.5%, and the resonator reflection factor in directly under [ of the 1st adjustment layer 98 which makes p lateral electrode serve a double purpose ] was able to become low with about 70%, and was able to control the laser oscillation of the high order transverse mode appropriately.

[0102] In addition, you may make it etching remove the part of the 2nd adjustment layer 96 located focusing on the outgoing radiation of a laser beam like an example 2. Moreover, instead of etching removing, as the gestalt of the 2nd operation also explained, the laminating of the reflection property amendment layer may be carried out on the 2nd adjustment layer 96 in a center section. Moreover, also in this example 3, like an example 1, although AlGaAs was used as an ingredient of a barrier layer, VCSEL for near-infrared can also be constituted using GaAs or InGaAs, and VCSEL for red can also be constituted using InGaP or AlGaInP. Furthermore, VCSEL for 1.3-1.5-micrometer bands can also be constituted using a VCSEL and InGaAsP system etc. for blue or ultraviolet rays using a GaN system, a ZnSe system, etc.

[0103] [an example 4] -- it is shown in drawing 13 -- as -- the n mold GaAs substrate 91 top -- MOCVD -- carrier concentration carries out the laminating of the n mold GaAs buffer layer 92 whose thickness is about 0.2 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$  by law.

[0104] this buffer layer 92 top -- MOCVD -- by law, the 40.5 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is carried out by turns so that each optical thickness may be set to one fourth of the wavelength in a medium, and carrier concentration forms [ the total thickness ] the lower n mold DBR layer 93 which is about 4 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$ .

[0105] this lower n mold DBR layer 93 top -- MOCVD -- with an undoping lower aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As spacer layer by law Undoping quantum well barrier layer (with three layers of aluminum<sub>0.11</sub>Ga<sub>0.89</sub>As quantum well layers of 90nm of thickness) The thickness constituted by the undoping up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As spacer layer as consisting of four layers of aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As barrier layers of 50nm of thickness forms the barrier layer field 94 used as the wavelength in a medium.

[0106] this barrier layer field 94 top -- MOCVD -- by law, 20 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is carried out by turns so that each optical thickness may be set to one fourth of the wavelength in a medium, and carrier concentration forms [ the total thickness ] the up p mold DBR layer 95 which is about 2 micrometers by  $1 \times 10^{18} \text{cm}^{-3}$ .

[0107] Besides, the 2nd adjustment layer 96 of aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As from which optical thickness is set to one fourth of the wavelength in a medium by undoping is inserted in a part of periphery in the section p mold DBR layer 95. This 2nd adjustment layer 96 of aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As is formed in the location where 5 period laminating of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As which are a part of up p mold DBR layer 95 under it is carried out by turns.

[0108] In this example 4, this aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As by which 5 period laminating was carried out, and an aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As layer demonstrate the function of the 1st adjustment layer 98 by being located between the 2nd adjustment layer 96 and the undoping up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As spacer layer of the barrier layer field 94. That is, the reflection factor and effective refractive index of a laser cavity in that part will fall by this aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As by which 5 period laminating was carried out, the aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As layer (the 1st adjustment layer 98), the 2nd adjustment layer 96 located in right above [ of it ], and the DBR layer 95.

[0109] In addition, when the 2nd adjustment layer 96 is inserted in right above [ of the undoping up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As spacer layer of the barrier layer field 94 ], the effectiveness of reducing the reflection factor and effective refractive index of a laser cavity in the part is not fully acquired.

[0110] Here, although not illustrated, carrier concentration may carry out the laminating of the p mold GaAs contact layer whose thickness is about 10nm to the topmost part by  $1 \times 10^{19} \text{cm}^{-3}$ . Moreover, although not stated in detail, in order to lower electric resistance of the DBR layers 93 and 95, the

thickness which changed [% / 30 ] the AlAs presentation from 90% to the interface of aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As gradually may prepare the field which is about 9nm.

[0111] Also in this example 4, like an example 1, it etches to the middle of the lower n mold DBR layer 93, the post S which consists of the cylinder or prism whose path is about 10-30 micrometers is formed, and this forms the current narrow segment. The SiN layer 97 is vapor-deposited by the circumference of Post S, and the pars basilaris ossis occipitalis of Post S. Moreover, it is vapor-deposited by the upper part of Post S by the thickness Ti and whose Au are 10nm and 300nm, respectively, the p lateral electrode 101 is formed in it, and the center section is removed. Although not illustrated in the rear face of a substrate 91, AuGe is vapor-deposited as an n lateral electrode. Although outgoing radiation of the laser light is carried out from the outgoing radiation field of the laser beam of the part in which the p lateral electrode 101 does not exist, i.e., the center section of the post S, the aperture of this outgoing radiation field has desirable about 3-20 micrometers.

[0112] The 2nd adjustment layer 96 of aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As inserted into the p mold DBR layer 95 in this example 4, By forming aluminum<sub>0.9</sub>Ga<sub>0.1</sub>As and aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As which are directly under the 2nd adjustment layer 96 which functions as the 1st adjustment layer and by which 5 period laminating was carried out The resonator reflection factor in directly under [ based on / of the laser beam of the center section of the post S / outgoing radiation ] was as high as about 99.5%, and the resonator reflection factor in directly under [ of the 2nd adjustment layer 96 ] was able to become low like the result shown in drawing 4 , and was able to control the laser oscillation of the high order transverse mode appropriately.

[0113] Although constituted using aluminum<sub>0.3</sub>Ga<sub>0.7</sub>As, the 2nd adjustment layer 96 can also consist of this example 4 using other ingredients, if it is the ingredient into which the reflection factor and/or effective refractive index of a laser cavity in directly under [ of the 2nd adjustment layer 96 ] can be reduced. Moreover, as the 2nd adjustment layer 96, although the undoping layer was used, n mold or p type layer can also be used. When an undoping layer or n type layer is used, the advantage to which 2nd adjustment layer 96 the very thing also demonstrates a current constriction function is acquired. The 1st adjustment layer 98 as well as example 1 grade can also constitute using other ingredients.

[0114] Moreover, although it etches to the middle of the lower n mold DBR layer 93 and Post S is formed in this example 4, from an up aluminum<sub>0.5</sub>Ga<sub>0.5</sub>As SU \*\*-sir layer or it, etching may be suspended in the upper part, Post S may be formed, and it may etch to right above [ of a substrate 91 ], and Post S may be formed.

[0115] Moreover, although AlGaAs was used as an ingredient of a barrier layer, VCSEL for near-infrared can also be constituted using GaAs or InGaAs, and VCSEL for red can also consist of this example 4 using InGaP or AlGaInP. Furthermore, VCSEL for 1.3-1.5-micrometer bands can also be constituted using a VCSEL and InGaAsP system etc. for blue or ultraviolet rays using a GaN system, a ZnSe system, etc.

[0116] Moreover, an insulator layer can also be used by not being limited to a semiconductor material and choosing various current impregnation methods as an ingredient of the DBR layers 93 and 95. When using an insulator layer as an ingredient of the DBR layers 93 and 95, it is desirable to use an insulator layer rather than a semi-conductor also as an ingredient of the 2nd adjustment layer 96.

[0117] Moreover, although irregularity may generate only that part on the top face of the p mold DBR95 as shown in drawing 14 when the 2nd adjustment layer 96 is formed using a re-growth technique, although this example 4 showed the example with the flat top face of the p mold DBR layer 95, the same effectiveness can be acquired even in this case.

[0118] [Example 5] As shown in drawing 15 , an example 5 arranges two or more VCSEL components 150 of the same structure as the structure shown in the example 1 on the same substrate, and constitutes a VCSEL array. In this example 5, in order to separate each VCSEL component 150 of each other electrically, the slot 151 is formed between the VCSEL components 150. Although only the cross section of an one direction is shown in drawing 15 , also in the depth direction, the slot 151 dissociates electrically.

[0119] In addition, in this example 5, although the slot 151 is used as an electric separation means, other



means, such as an approach of preparing a high resistance field by ion implantation, can also be used. [0120] Moreover, although the thing of the postmold shown in the example 1 is used as each VCSEL component 150 which constitutes a VCSEL array, the thing of the selective oxidation mold of an example 2 and the ion-implantation mold of an example 3 can also be used.

[0121] Moreover, not only two-dimensional but at least one dimension of configuration methods of a VCSEL array does not interfere. every -- an independent drive mold may be used for the drive of the VCSEL component 150 -- it may carry out, a matrix drive mold may be used, and a coincidence drive mold may be used further.

[0122] every -- since the membrane formation means excellent in the homogeneity within a field is used in production of the VCSEL component 150, even if a VCSEL array becomes large-scale -- every -- the property variation between the VCSEL components 150 has the advantage which becomes very small.

[0123] In the above example, what combined the gestalt of the 1st operation and the postmold VCSEL is made into an example 1. Although what combined the AIAs selective oxidation mold VCSEL as the gestalt and current constriction structure of the 2nd operation was made into the example 2 and what combined the proton in plastic mold VCSEL as the gestalt and current constriction structure of the 3rd operation was made into the example 3 Even if it is not limited to such combination and changes combination suitably, the purpose of this invention can be attained.

[0124]

[Effect of the Invention] According to this invention, as explained above, repeatability is good, it is a high yield and VCSEL and the VCSEL array which have a high brightness basic transverse-mode optical output can be manufactured cheaply. Therefore, VCSEL and the VCSEL array concerning this invention can fully be used also for the application as which high brightness basic transverse-mode optical outputs, such as printer equipment and optical-magnetic disc equipment, are required.

---

[Translation done.]



\* NOTICES \*

JPO and NCIPi are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

## DESCRIPTION OF DRAWINGS

---

### [Brief Description of the Drawings]

[Drawing 1] The graph which shows the optical intensity distribution when carrying out laser oscillation of the sectional view simplifying and showing the structure of VCSEL which (a) requires for this invention, and the (b) by the basic transverse mode, and (c) are graphs which show the optical intensity distribution when carrying out laser oscillation by the high order transverse mode.

[Drawing 2] It is VCSEL concerning this invention, and it is a sectional view although it has refractive-index waveguide structure.

[Drawing 3] It is the sectional view of VCSEL concerning the gestalt of operation of the 1st of this invention.

[Drawing 4] It is the graph which shows the relation between the optical thickness of the 2nd adjustment layer, and the amplitude reflectance in the laser oscillation wavelength of 780nm.

[Drawing 5] It is the graph which shows a reflectance spectrum on the strength in case the optical thickness of the 2nd adjustment layer is abbreviation 1.6x quarter-wave length, and is a thing in case (a) does not start the gestalt of operation of this invention and (b) does not prepare the 1st adjustment layer.

[Drawing 6] (a) And (b) is the sectional view of VCSEL which starts the gestalt of operation of the 2nd of this invention, respectively.

[Drawing 7] It is the graph which shows the reflectance spectrum of an up reflecting layer on the strength.

[Drawing 8] It is the sectional view of VCSEL concerning the gestalt of operation of the 3rd of this invention.

[Drawing 9] (e) is the sectional view showing the production process of VCSEL concerning the example 1 of this invention in order from (a).

[Drawing 10] It is the graph which shows the relation of the optical output and inrush current in VCSEL and the conventional VCSEL concerning the example 1 of this invention.

[Drawing 11] It is the sectional view of VCSEL concerning the example 2 of this invention.

[Drawing 12] It is the sectional view of VCSEL concerning the example 3 of this invention.

[Drawing 13] It is the sectional view of VCSEL concerning the example 4 of this invention.

[Drawing 14] It is the sectional view of VCSEL concerning the example 4 of this invention.

[Drawing 15] It is the sectional view of the VCSEL array concerning the example 5 of this invention.

[Drawing 16] It is the sectional view of VCSEL of the conventional proton in plastic mold.

[Drawing 17] It is the sectional view of the conventional VCSEL which has the loss determiner of a concave configuration.

[Drawing 18] It is the sectional view showing in order the production process of the loss determiner in the conventional VCSEL which has a loss determiner.

### [Description of Notations]

11 Barrier Layer Field

12 Up Reflecting Layer

13 Lower Reflecting Layer

14 1st Adjustment Layer  
15 2nd Adjustment Layer  
16 Reflection Property Amendment Layer  
91 N Mold GaAs Substrate  
92 N Mold GaAs Buffer Layer  
93 Lower N Mold DBR Layer  
94 Barrier Layer Field  
95 Up P Mold DBR Layer  
96 2nd Adjustment Layer  
97 SiN Layer  
98 1st Adjustment Layer  
S Post  
R Resist  
T Resist pattern  
99 P Mold AlAs Layer  
100 High Resistance Field  
101 P Lateral Electrode  
150 VCSEL  
151 Slot  
161 Lower N Mold DBR Layer  
162 Barrier Layer Field  
163 Up P Mold DBR Layer  
164 P Lateral Electrode  
165 High Resistance Field  
166 Outgoing Radiation Field  
171 Conductivity-Type Semi-conductor Substrate  
172 Lower DBR Layer  
173 Barrier Layer Field  
174 Up DBR Layer  
175 Low Reflection Factor Zone  
176 Loss Determiner  
177 178 Electrode  
179 Optical Axis  
181 Layer Which is Going to Form Curve Front Face  
182 Photoresist  
183 Cylindrical Shape Photoresist Column  
184 Layer of Configuration Which Has Convex Curve Side  
185 Structure of Having Convex Curve Side

---

[Translation done.]

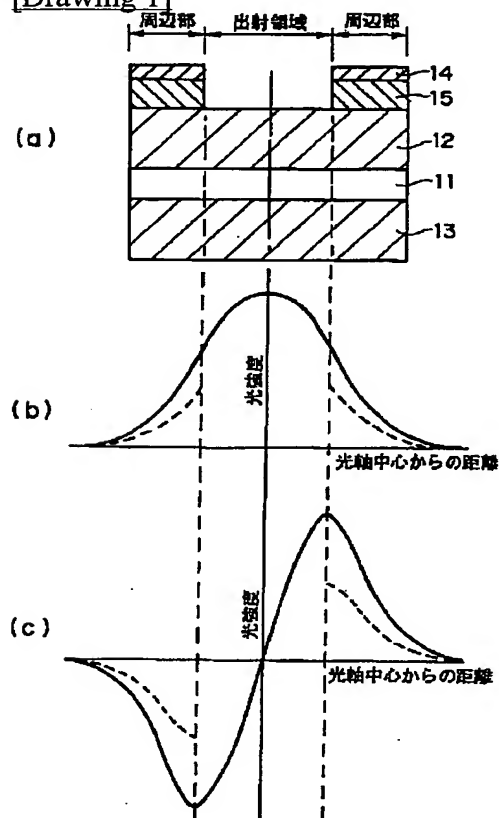
## \* NOTICES \*

JPO and NCIPi are not responsible for any damages caused by the use of this translation.

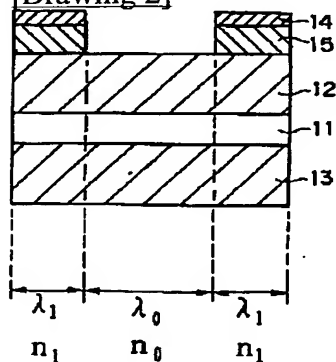
1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

## DRAWINGS

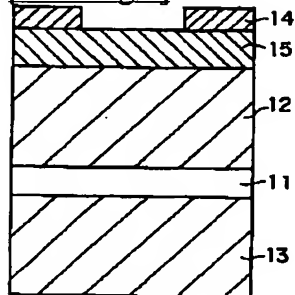
[Drawing 1]



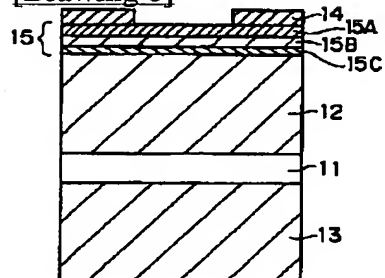
[Drawing 2]



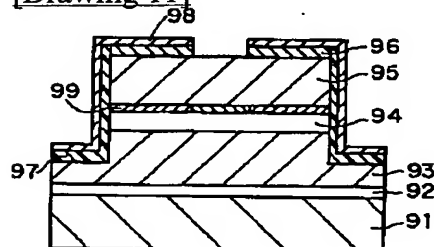
[Drawing 3]



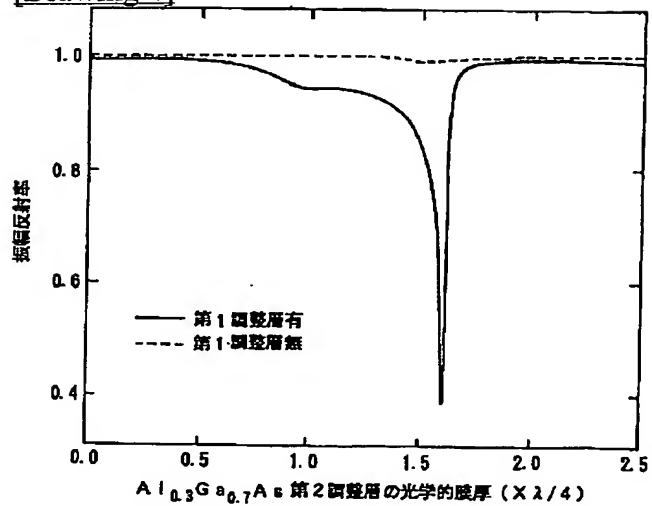
[Drawing 8]



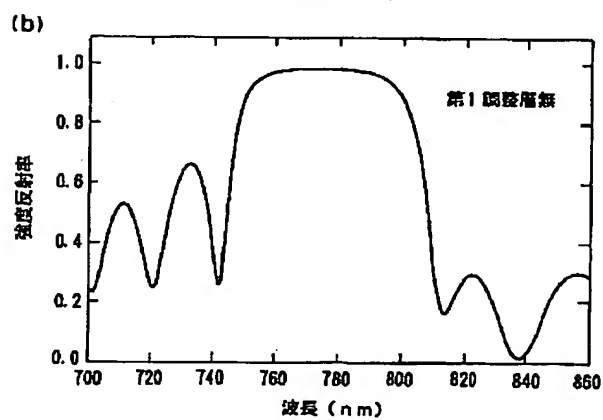
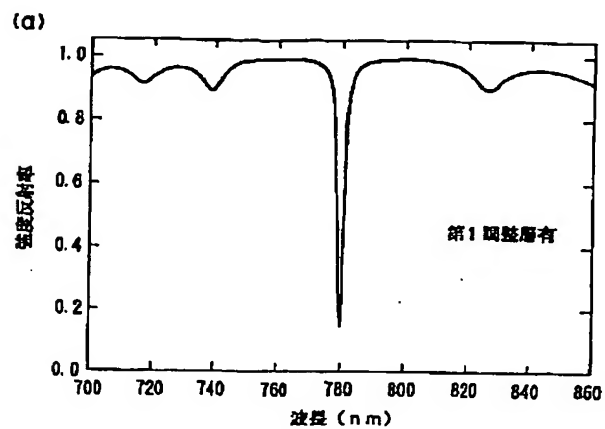
[Drawing 11]



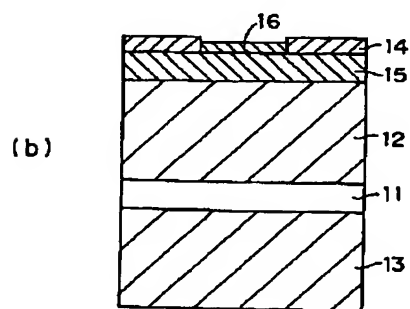
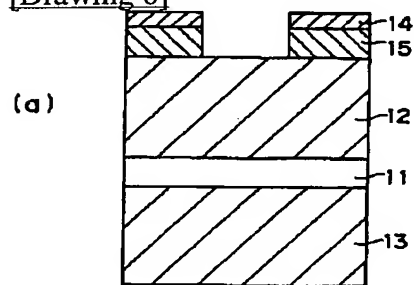
[Drawing 4]



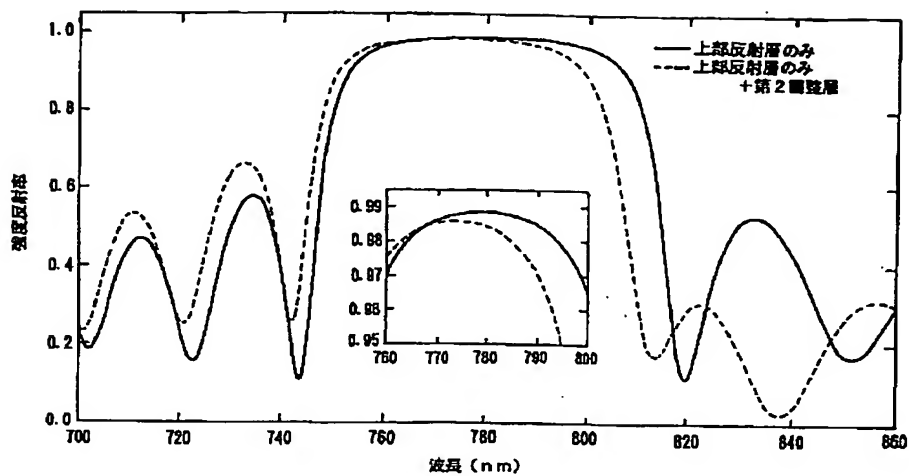
[Drawing 5]



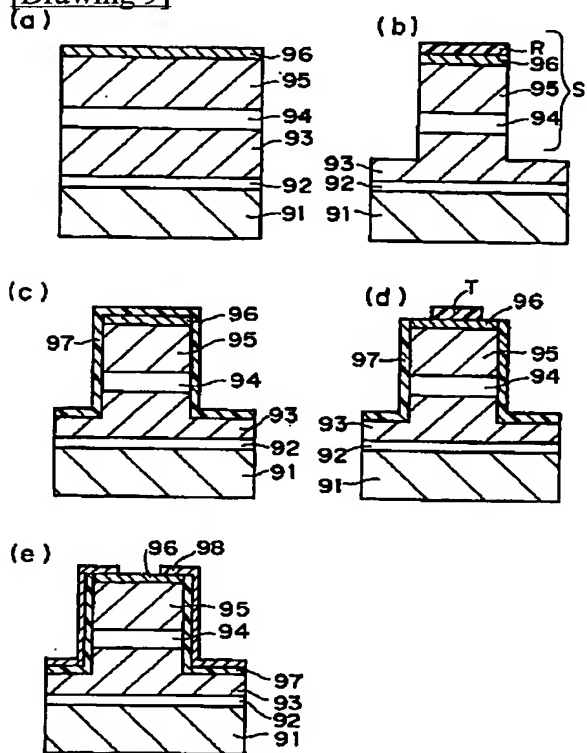
[Drawing 6]



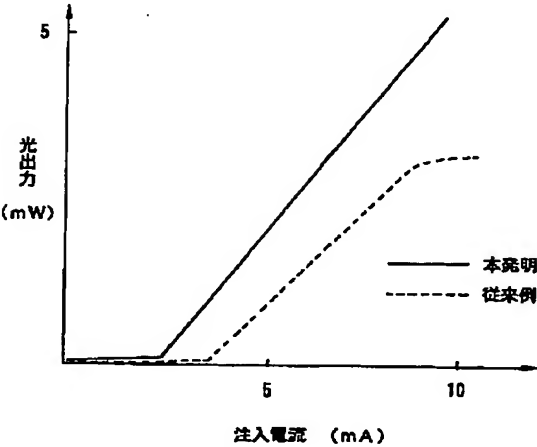
[Drawing 7]



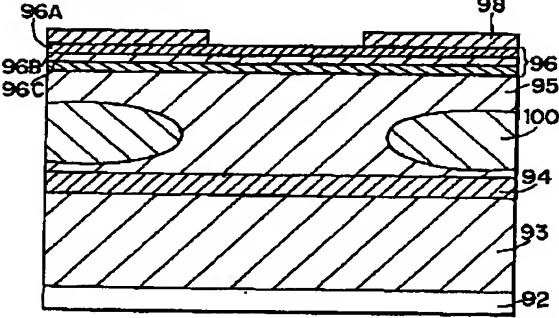
[Drawing 9]



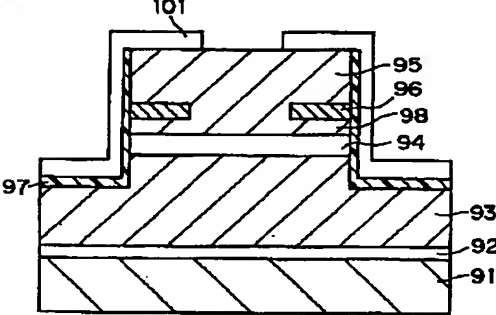
[Drawing 10]



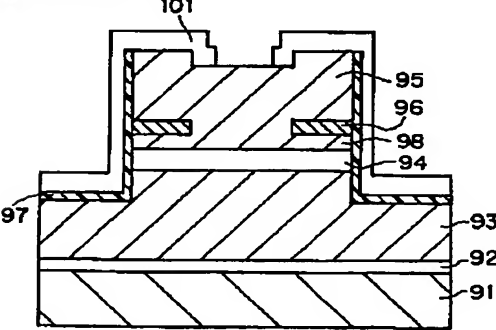
[Drawing 12]



[Drawing 13]

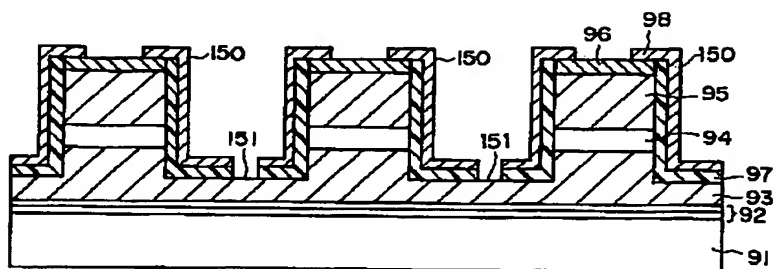


[Drawing 14]

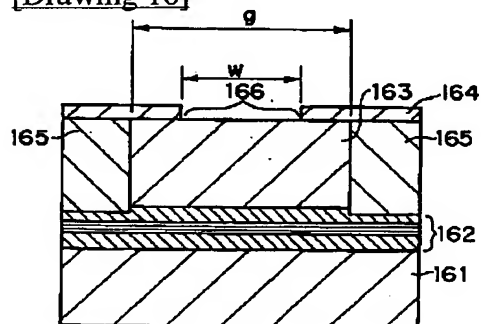


[Drawing 15]

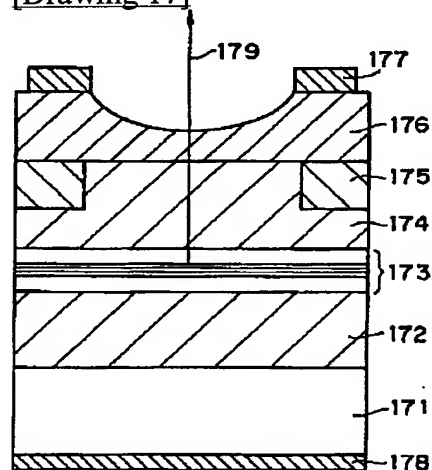




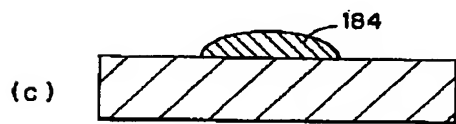
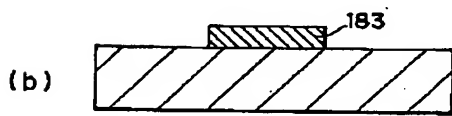
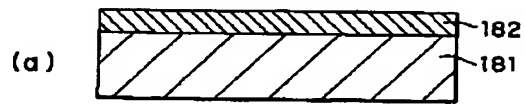
[Drawing 16]



[Drawing 17]



[Drawing 18]




---

[Translation done.]

\* NOTICES \*

JPO and NCIPi are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

CORRECTION OR AMENDMENT

---

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law  
[Section partition] The 2nd partition of the 7th section  
[Publication date] February 14, Heisei 15 (2003. 2.14)

[Publication No.] JP,2000-22271,A (P2000-22271A)  
[Date of Publication] January 21, Heisei 12 (2000. 1.21)  
[Annual volume number] Open patent official report 12-223  
[Application number] Japanese Patent Application No. 10-190701  
[The 7th edition of International Patent Classification]

H01S 5/30

[FI]

H01S 3/18

[Procedure revision]  
[Filing Date] November 7, Heisei 14 (2002. 11.7)  
[Procedure amendment 1]  
[Document to be Amended] Specification  
[Item(s) to be Amended] Claim  
[Method of Amendment] Modification  
[Proposed Amendment]  
[Claim(s)]

[Claim 1] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the location which receives a laser beam before the outgoing radiation of a laser beam at least, and reflects a laser beam in said reflecting layer side,

The 2nd adjustment layer of the translucency to which the phase of a laser beam reflected in said reflecting layer and said 1st adjustment layer is changed while incidence of the laser beam reflected in said reflecting layer and said 1st adjustment layer is carried out,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 2] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this

barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the location which receives a laser beam before the outgoing radiation of a laser beam at least, and reflects a laser beam in said reflecting layer side,

The 2nd adjustment layer of the translucency to which the multiple echo of the laser beam which carried out incidence is carried out between said reflecting layers and said 1st adjustment layers while incidence of the laser beam reflected in said reflecting layer and said 1st adjustment layer is carried out,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 3] The thickness of said 2nd adjustment layer is a surface emission-type laser according to claim 1 or 2 characterized by being the thickness which carries out laser oscillation by the basic transverse mode.

[Claim 4] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side,

The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least.

While a laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out By changing the phase of a laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer, and attenuating the synthetic wave of the laser beam after a phase change, and the laser beam which carried out incidence The 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 5] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side,

The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least.

While a laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out The 2nd adjustment layer of the translucency to which interference by the multiple echo is generated by said 1st adjustment layer, 2nd adjustment layer concerned, and said reflecting layer, and the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 6] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side,

The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least.

While a laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out The phase of a laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is changed. The 2nd adjustment layer of the translucency to which oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is made into a different thing from the oscillation wavelength of the laser beam in the outgoing radiation core of said laser beam, and the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced,  
a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 7] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side,

The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least. While a laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out The 2nd adjustment layer of the translucency to which interference by the multiple echo is generated by said 1st adjustment layer, 2nd adjustment layer concerned, and said reflecting layer, and the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 8] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ said / at least ] reflecting layer side,

The outgoing radiation core of the laser beam generated in said barrier layer field is a periphery at least. While a laminating is carried out between one [ said / at least ] reflecting layer and said 1st adjustment layer and incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out The 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced while shifting the wavelength which resonates by said 1st adjustment layer, 2nd adjustment layer concerned, and said reflecting layer to a short wavelength side rather than the oscillation wavelength of a laser beam,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 9] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out between one [ at least ] spacer layers and reflecting layers of an outside, and reflects a laser beam in one [ said / at least ] spacer layer side,

The 2nd adjustment layer of the translucency to which it is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and is located between one [ said / at least ] reflecting layer and the 1st adjustment layer, incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out, and the reflection factor to the

oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 10] Said 2nd adjustment layer is a surface emission-type laser according to claim 9 characterized by changing the phase of a laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer, and attenuating the synthetic wave of the laser beam after a phase change, and the laser beam which carried out incidence.

[Claim 11] In the surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively,

The 1st adjustment layer which is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, and a laminating is carried out between one [ at least ] spacer layers and reflecting layers of an outside, and reflects a laser beam in one [ said / at least ] spacer layer side,

The 2nd adjustment layer of the translucency to which it is a periphery based on [ of the laser beam generated in said barrier layer field ] outgoing radiation, incidence of the laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is carried out, and the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is reduced,

a \*\*\*\* beam -- the surface emission-type laser characterized by things.

[Claim 12] For the oscillation wavelength of a laser beam [ in / for the oscillation wavelength of a laser beam / in / the phase of a laser beam reflected in one / said / at least / reflecting layer and said 1st adjustment layer is changed, and / the periphery based on / of said laser beam / outgoing radiation / the outgoing radiation core of said laser beam ], said 2nd adjustment layer is a surface emission-type laser according to claim 11 characterized by making it a different thing.

[Claim 13] Said 1st adjustment layer is the surface emission-type laser of 12 claim 9 characterized by making serve a double purpose and constituting said a part of reflecting layer thru/or given in any 1 term.

[Claim 14] Claim 1 characterized by having differed in the part in which the optical thickness of said 2nd adjustment layer is located focusing on the outgoing radiation of a laser beam, and the part located in the periphery, and making high the reflection factor to the oscillation wavelength of the laser beam in the outgoing radiation core of a laser beam thru/or the surface emission-type laser of 13 given in any 1 term.

[Claim 15] Claim 1 characterized by preparing the reflection property amendment layer which makes high the reflection factor to the oscillation wavelength of the laser beam in the outgoing radiation core of a laser beam in a part of part [ at least ] located focusing on the outgoing radiation of the laser beam in said 2nd adjustment layer thru/or the surface emission-type laser of 14 given in any 1 term.

[Claim 16] Said 2nd adjustment layer is the surface emission-type laser of 15 claim 1 characterized by consisting of one kind or two kinds or more of ingredients, or a presentation thru/or given in any 1 term.

[Claim 17] Said 1st adjustment layer is the surface emission-type laser of 15 claim 1 characterized by consisting of one kind or two kinds or more of ingredients, or a presentation thru/or given in any 1 term.

[Claim 18] Said 1st adjustment layer is the surface emission-type laser of eight claim 1 characterized by consisting of metals and making one electrode serve a double purpose thru/or given in any 1 term.

[Claim 19] Said 1st adjustment layer is the surface emission-type laser of 17 claim 1 characterized by consisting of semi-conductor multilayers thru/or given in any 1 term.

[Claim 20] Said 1st adjustment layer is the surface emission-type laser of 17 claim 1 characterized by consisting of dielectric multilayers thru/or given in any 1 term.

[Claim 21] Claim 1 characterized by current constriction structure being a postmold thru/or the surface emission-type laser of 20 given in any 1 term.

[Claim 22] Claim 1 characterized by current constriction structure being a selective oxidation mold thru/or the surface emission-type laser of 20 given in any 1 term.

[Claim 23] Claim 1 characterized by current constriction structure being a proton placing mold thru/or the surface emission-type laser of 20 given in any 1 term.

[Claim 24] The field luminescence laser array characterized by coming to arrange two or more surface emission-type lasers of 23 claim 1 thru/or given in any 1 term in the shape of an array.

[Procedure amendment 2]

[Document to be Amended] Specification

[Item(s) to be Amended] 0020

[Method of Amendment] Modification

[Proposed Amendment]

[0020]

[Means for Solving the Problem] this invention person etc. came to complete header this invention for the above-mentioned technical problem being solvable with the following means, as a result of inquiring wholeheartedly. That is, the surface emission-type laser of this invention is characterized by having the following. The barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation in the surface emission-type laser which comes to have the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively, and a laminating is carried out to the location which receives a laser beam before the outgoing radiation of a laser beam at least, and reflects a laser beam in a reflecting layer side The 2nd adjustment layer of the translucency to which the phase of a laser beam reflected in the reflecting layer and the 1st adjustment layer is changed while incidence of the laser beam reflected in the reflecting layer and said 1st adjustment layer is carried out Moreover, the 2nd adjustment layer may be the 2nd adjustment layer of the translucency to which the multiple echo of the laser beam which carried out incidence is carried out between said reflecting layers and said 1st adjustment layers while incidence of the laser beam reflected in the reflecting layer and the 1st adjustment layer is carried out. As for the thickness of these 2nd adjustment layer, it is desirable that it is the thickness which carries out laser oscillation by the basic transverse mode.

[Procedure amendment 3]

[Document to be Amended] Specification

[Item(s) to be Amended] 0021

[Method of Amendment] Modification

[Proposed Amendment]

[0021] The surface emission-type laser which comes to have the barrier layer field which consists of a spacer layer to which this invention carried out the laminating of an example of the surface emission-type laser of this invention to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively is characterized by providing the following. The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ at least ] reflecting layer side While the outgoing radiation core of the laser beam generated in the barrier layer field is a periphery at least, a laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out By changing the phase of a laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer, and attenuating the synthetic wave of the laser beam after a phase change, and the laser beam which carried out incidence The 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced The outgoing radiation core of a laser beam of having generated the 2nd adjustment layer in the barrier layer field is a periphery at least. While a laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out By changing the phase of a laser beam reflected in one [ at least ] reflecting layer and 1st



adjustment layer, and attenuating the synthetic wave of the laser beam after a phase change, and the laser beam which carried out incidence It can consider as the 2nd adjustment layer of the translucency to which the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced. Moreover, the outgoing radiation core of a laser beam of having generated the 2nd adjustment layer in the barrier layer field is a periphery at least. While a laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out It is good also as the 2nd adjustment layer of the translucency to which interference by the multiple echo is generated by the 1st adjustment layer, the 2nd adjustment layer, and the reflecting layer, and the reflection factor to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

[Procedure amendment 4]

[Document to be Amended] Specification

[Item(s) to be Amended] 0022

[Method of Amendment] Modification

[Proposed Amendment]

[0022] The surface emission-type laser for which an example of everything [ this invention ] but the surface emission-type laser of this invention comes to prepare the barrier layer field which consists of a spacer layer which carried out the laminating to the both sides of a barrier layer and this barrier layer, respectively, and the reflecting layer which carried out the laminating to the both sides of this barrier layer field, respectively is characterized by providing the following. The 1st adjustment layer which is a periphery based on [ of the laser beam generated in the barrier layer field ] outgoing radiation, and a laminating is carried out to the outside of one [ at least ] reflecting layer, and reflects a laser beam in one [ at least ] reflecting layer side While the outgoing radiation core of the laser beam generated in the barrier layer field is a periphery at least, a laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out The phase of a laser beam reflected in one [ said / at least ] reflecting layer and said 1st adjustment layer is changed. The 2nd adjustment layer of the translucency to which oscillation wavelength of the laser beam in the periphery based on [ of said laser beam ] outgoing radiation is made into a different thing from the oscillation wavelength of the laser beam in the outgoing radiation core of said laser beam, and the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced The outgoing radiation core of a laser beam of having generated the 2nd adjustment layer in the barrier layer field is a periphery at least. While a laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out Interference by the multiple echo is generated by the 1st adjustment layer, the 2nd adjustment layer, and the reflecting layer, and it can consider as the 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced. Moreover, the outgoing radiation core of a laser beam of having generated the 2nd adjustment layer in the barrier layer field is a periphery at least. While a laminating is carried out between one [ at least ] reflecting layer and the 1st adjustment layer and incidence of the laser beam reflected in one [ at least ] reflecting layer and 1st adjustment layer is carried out While shifting the wavelength which resonates by the 1st adjustment layer, the 2nd adjustment layer, and the reflecting layer to a short wavelength side rather than the oscillation wavelength of a laser beam, it is good also as the 2nd adjustment layer of the translucency to which the effective refractive index to the oscillation wavelength of the laser beam in the periphery based on [ of a laser beam ] outgoing radiation is reduced.

---

[Translation done.]

(19) 日本国特許庁 (J P)

(12) 公開特許公報 (A)

(11) 特許出願公開番号  
特開2000-22271  
(P2000-22271A)

(43) 公開日 平成12年1月21日 (2000.1.21)

(51) Int.Cl.  
H 0 1 S 5/30

識別記号

F I  
H 0 1 S 3/18

テマコード (参考)  
5 F 0 7 3

審査請求 未請求 請求項の数28 O L (全 18 頁)

(21) 出願番号 特願平10-190701  
(22) 出願日 平成10年7月6日 (1998.7.6)

(71) 出願人 000005496  
富士ゼロックス株式会社  
東京都港区赤坂二丁目17番22号  
(72) 発明者 中山 秀生  
神奈川県足柄上郡中井町境430 グリーン  
テクなかい 富士ゼロックス株式会社内  
(72) 発明者 坂本 朗  
神奈川県足柄上郡中井町境430 グリーン  
テクなかい 富士ゼロックス株式会社内  
(74) 代理人 100079049  
弁理士 中島 淳 (外3名)

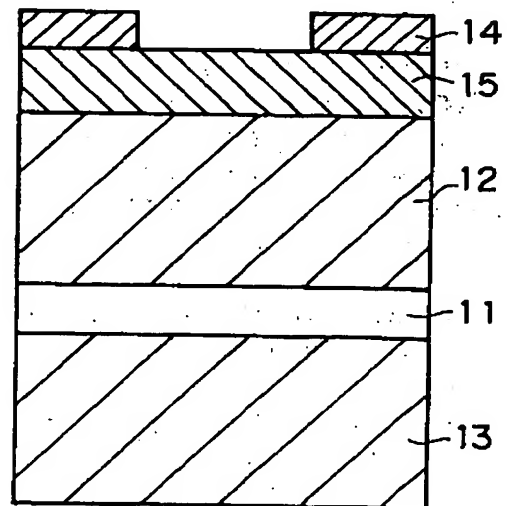
最終頁に続く

(54) 【発明の名称】 面発光レーザおよび面発光レーザアレイ

(57) 【要約】

【課題】 位置バラツキが小さく、かつ、再現性よく、しかも、容易に作製することができる高輝度基本横モード光出力を有する面発光レーザおよび面発光レーザアレイを提供する。

【解決手段】 活性層とこの活性層の両側に積層した上部スペーサ層および下部スペーサ層とからなる活性層領域11と、この活性層領域11の上部スペーサ層に積層した上部反射層12と、活性層領域11の下部スペーサ層に積層した下部反射層13と、上部反射層12におけるレーザ光の出射領域の周辺部に、第1調整層14と第2調整層15とを設けて副次的な共振器を形成する。



(2)

## 【特許請求の範囲】

【請求項 1】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくともレーザ光の出射前にレーザ光を受ける位置に積層され、レーザ光を前記反射層の側に反射する第 1 調整層と、

前記反射層と前記第 1 調整層とで反射されたレーザ光が入射される透光性の第 2 調整層とを設けたことを特徴とする面発光レーザ。

【請求項 2】 前記第 2 調整層は、前記反射層と前記第 1 調整層とで反射されたレーザ光の位相を変化させることを特徴とする請求項 1 記載の面発光レーザ。

【請求項 3】 前記第 2 調整層は、入射したレーザ光を前記反射層と前記第 1 調整層との間で多重反射させることを特徴とする請求項 1 記載の面発光レーザ。

【請求項 4】 前記第 2 調整層の膜厚は、基本横モードでレーザ発振する膜厚であることを特徴とする請求項 1 から 3 までのいずれか一記載の面発光レーザ。

【請求項 5】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第 1 調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前記第 1 調整層との間に積層され、前記少なくとも一方の反射層と前記第 1 調整層とで反射されたレーザ光が入射されて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第 2 調整層とを設けたことを特徴とする面発光レーザ。

【請求項 6】 前記第 2 調整層は、前記少なくとも一方の反射層と前記第 1 調整層とで反射されたレーザ光の位相を変化させ、位相変化後のレーザ光と入射したレーザ光との合成波を減衰させることを特徴とする請求項 5 記載の面発光レーザ。

【請求項 7】 前記第 2 調整層は、前記第 1 調整層と当該第 2 調整層と前記反射層とによって多重反射による干渉を発生させて当該反射層の反射率を低下させるものであることを特徴とする請求項 5 記載の面発光レーザ。

【請求項 8】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部

であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第 1 調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前記第 1 調整層との間に積層され、前記少なくとも一方の反射層と前記第 1 調整層とで反射されたレーザ光が入射されて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第 2 調整層とを設けたことを特徴とする面発光レーザ。

【請求項 9】 前記第 2 調整層は、前記少なくとも一方の反射層と前記第 1 調整層とで反射されたレーザ光の位相を変化させ、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長を前記レーザ光の出射中心におけるレーザ光の発振波長とは異なるものにしたことを特徴とする請求項 8 記載の面発光レーザ。

【請求項 10】 前記第 2 調整層は、前記第 1 調整層と当該第 2 調整層と前記反射層とによって多重反射による干渉を発生させてレーザ光の出射中心の周辺部における実効屈折率を低下させるものであることを特徴とする請求項 8 記載の面発光レーザ。

【請求項 11】 前記第 2 調整層は、前記第 1 調整層と当該第 2 調整層と前記反射層とによって共振する波長をレーザ光の発振波長よりも短波長側にシフトさせるとともにレーザ光の出射中心の周辺部における実効屈折率を低下させるものであることを特徴とする請求項 8 記載の面発光レーザ。

【請求項 12】 前記第 2 調整層の光学的膜厚がレーザ光の出射中心に位置する部分とその周辺部に位置する部分とで異なり、レーザ光の出射中心におけるレーザ光の発振波長に対する反射率を高くしたことを特徴とする請求項 1 から 11 までのいずれか一記載の面発光レーザ。

【請求項 13】 前記第 2 調整層におけるレーザ光の出射中心に位置する部分の少なくとも一部に、レーザ光の出射中心におけるレーザ光の発振波長に対する反射率を高くする反射特性補正層を設けたことを特徴とする請求項 1 から 12 までのいずれか一記載の面発光レーザ。

【請求項 14】 前記第 2 調整層は、1 種類または 2 種類以上の材料または組成からなることを特徴とする請求項 1 から 13 までのいずれか一記載の面発光レーザ。

【請求項 15】 前記第 1 調整層は、1 種類または 2 種類以上の材料または組成からなることを特徴とする請求項 1 から 14 までのいずれか一記載の面発光レーザ。

【請求項 16】 前記第 1 調整層は、金属で構成され、一方の電極を兼用することを特徴とする請求項 1 から 15 までのいずれか一記載の面発光レーザ。

【請求項 17】 前記第 1 調整層は、半導体多層膜で構成されたことを特徴とする請求項 1 から 15 までのいずれか一記載の面発光レーザ。

(3)

3

【請求項18】 前記第1調整層は、誘電体多層膜で構成されたことを特徴とする請求項1から15までのいずれか一記載の面発光レーザ。

【請求項19】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方のスペーサ層とその外側の反射層との間に積層され、レーザ光を前記少なくとも一方のスペーサ層の側に反射する第1調整層と、前記活性層領域で発生したレーザ光の出射中心の周辺部であって、前記少なくとも一方の反射層と第1調整層との間に位置し、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層とを設けたことを特徴とする面発光レーザ。

【請求項20】 前記第2調整層は、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、位相変化後のレーザ光と入射したレーザ光との合成波を減衰させることを特徴とする請求項19記載の面発光レーザ。

【請求項21】 前記第1調整層は、前記反射層の一部を兼用して構成したことを特徴とする請求項19記載の面発光レーザ。

【請求項22】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方のスペーサ層とその外側の反射層との間に積層され、レーザ光を前記少なくとも一方のスペーサ層の側に反射する第1調整層と、前記活性層領域で発生したレーザ光の出射中心の周辺部であって、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層とを設けたことを特徴とする面発光レーザ。

【請求項23】 前記第2調整層は、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長を前記レーザ光の出射中心におけるレーザ光の発振波長とは異なるものにしたことを特徴とする請求項22記載の面発光レーザ。

【請求項24】 前記第1調整層は、前記反射層の一部を兼用して構成したことを特徴とする請求項22記載の面発光レーザ。

【請求項25】 電流狭窄構造がポスト型であることを

4

特徴とする請求項1から24までのいずれか一記載の面発光レーザ。

【請求項26】 電流狭窄構造が選択酸化型であることを特徴とする請求項1から24までのいずれか一記載の面発光レーザ。

【請求項27】 電流狭窄構造がプロトン打ち込み型であることを特徴とする請求項1から24までのいずれか一記載の面発光レーザ。

【請求項28】 請求項1から27までのいずれか一記載の面発光レーザを複数個アレイ状に配列してなることを特徴とする面発光レーザアレイ。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、面発光レーザおよび面発光レーザアレイに関するものであり、特に、高輝度基本横モード光出力を有する垂直共振器型面発光レーザおよび面発光レーザアレイに関するものである。

【0002】

【従来の技術】垂直共振器型面発光レーザ (Vertical Cavity Surface Emitting Laser、以下「VCSEL」ともいう。) は、端面発光型レーザに比べて、製造コストが低いこと、製造の歩留まりが高いこと、2次元アレイ化が容易なこと、などの多くの利点を有していることから、近年、多くの用途に使用することが検討されている。例えば、Kenichi Iga, Fumio Koyama and Susumu Kinoshita, "Surface Emitting Semiconductor Lasers", IEEE Journal of Quantum Electronics, 1988, 24, pp. 1845-1855には、VCSELの構造、レーザ特性、用途等が説明されている。現在においては、そのレーザ特性は大きく改善され、光通信などの分野では、実用化に至っている。しかし、従来のVCSELは、基本横モード光出力がいまだ小さく、せいぜい2~3mW程度であり、そのため用途が限定されている。VCSELの基本横モード光出力が増大して、例えば5mW以上となれば、レーザビームプリンタ等の画像書き込み装置や、光磁気ディスク装置等にも、VCSELを使用することが可能となる。

【0003】VCSELの基本横モード光出力を大きくするための技術としては、例えば、R. A. Morgan et al., "Transverse Mode Control of Vertical-Cavity Top-Surface-Emitting Lasers", IEEE Photonics Technology Letters, 4, pp. 374-377, 1993に記載されているように、レーザ光の出射領域の口径を適正化することにより基本横モード光出力を増加させるVCSEL構造が知られている。

(4)

5

【0004】このVCSEL構造は、一般的なプロトンインプラ型といわれるものであって、図16に示すように、図示しないn型GaAs基板上に、AlAsとAl<sub>0.16</sub>Ga<sub>0.84</sub>Asを28.5周期積層して、キャリア濃度が $3 \times 10^{18} \text{cm}^{-3}$ の下部n型DBR (Distributed Bragg Reflector) 層161を設けている。この下部n型DBR層161上には、量子井戸構造を持つ活性層とスペーサー層を含むアンドープ活性層領域162を設けている。この活性層領域162上には、Al<sub>0.58</sub>Ga<sub>0.42</sub>Asを界面に挟むAlAsとAl<sub>0.16</sub>Ga<sub>0.84</sub>Asを20周期積層して、キャリア濃度が $3 \times 10^{18} \text{cm}^{-3} \sim 2 \times 10^{19} \text{cm}^{-3}$ の上部p型DBR層163を設けている。さらに、上部p型DBR層163の上部には、レーザ光の出射領域166の口径Wが所定の値となるように開口させたp側電極164を設けている。上部p型DBR層163の周辺部には、活性層への電流注入領域を限定するために、プロトン打ち込みにより形成した高抵抗領域165を設けている。なお、図示しない基板の下部には、図示しないn側電極を設けている。

【0005】以上のような構造のVCSELにおいては、電流注入領域の大きさ(径g)と出射領域166の口径Wを適正化させることにより、基本横モード光出力を増加させることができるとしている。しかし、その基本横モード光出力の最大値はいまだ1.5mWにすぎず、このような小出力では光磁気ディスク装置等の用途に好適に使用することは困難である。

【0006】これに対して、特開平10-56233号には、高輝度基本横モード光出力を有するVCSELが提案されている。この提案では、基本横モード光出力の高出力化を、基本横モード以外に副次的に発生する高次横モードのレーザ発振条件を選択的に抑制することにより実現している。すなわち、VCSELにおける基本横モード発振は光導波路の中心(光軸に近接して)に生じ、高次横モード発振は光軸から離間した遠隔の位置において生じることから、光軸からの離間距離が増大するに従って共振器の光学損失を漸進的に増大させ、それによって注入電流値を増やしながらか多モード発振への移行を抑え、基本横モード光出力の増加を可能にしている。

【0007】具体的に説明すると、このVCSELは、図17に示すように、導電型半導体基板171と、下部DBR層172と、下部DBR層172とは逆の伝導モードを有する上部DBR層174と、下部DBR層172と上部DBR層174の間に挟まれた活性層領域173と、イオン打ち込み等により形成した低反射率ゾーン175と、損失決定素子176と、電極177及び178とにより構成され、光軸179に沿ってレーザ光が出射される。損失決定素子176は、光軸179と直交する方向において光軸179からの距離が増大するに従って共振器の光学損失を漸進的に増大させるために、凹

6

状の形状に加工されている。この凹状の形状の損失決定素子176は、共振器のレーザ光を屈折する作用と、共振器のレーザ光を側方に拡散させるか、または焦点をずらす作用の両方を有する。

【0008】したがって、この損失決定素子176により、光軸179と直交する方向における光軸179からの距離が増大するのに従って屈折損失が増大し、共振器の光学損失が大きくなる。一方、このVCSELにおける基本横モード発振は光軸179に近接して生じ、高次横モード発振は光軸179から離間した遠隔の位置において生じる。その結果、高次横モードに関して共振器の光学損失が増大し、高次横モードのレーザ発振の開始に必要とされるしきい値電流密度が増大し、最大基本横モード光出力が大幅に増大することになる。

【0009】

【発明が解決しようとする課題】以上のように、特開平10-56233号に開示された技術によれば、原理的には基本横モードの高出力化が可能となる。しかし、同時に、基本横モード特性にも悪影響を与えること、所定の形状の損失決定素子176を安定に形成することが著しく困難であること、等の問題を有している。

【0010】すなわち、特開平10-56233号に開示された技術では、上述したように、VCSELにおける基本横モード発振は光導波路の中心(光軸に近接して)に生じ、高次横モード発振は光軸から離間した遠隔の位置において生じることを利用して、共振器の反射率をその中央から周辺に向かうに従って漸進的に減少させ、すなわち、光学損失を漸進的に増大させ、そのことによって高次横モードのレーザ発振を抑制している。

【0011】一方、伊賀健一、小山二三夫著“面発光レーザ”(オーム社、1990)にも説明されているように、VCSELは、一般に、活性領域が小さいため、共振器には高い反射率が必要とされる。実際に、現在研究されているVCSELの共振器は、99%以上の反射率を有している。逆に、共振器の反射率が低いと、しきい値電流密度が上がり、レーザ発振が起こりにくくなる。

【0012】ところが、特開平10-56233号に開示された技術では、光軸179から少しでも離間した位置では、共振器の反射率が低下する構造となっており、高次横モードのレーザ発振を抑制するのみならず、基本横モードのレーザ発振も同時に抑制され、結果的には、十分な高輝度基本横モード光出力を得ることができない問題がある。

【0013】また、特開平10-56233号に開示された技術では、損失決定素子176は、図17に示したように凹状の形状とするか、または凸状の形状とすることにより、湾曲した表面を有することを特徴としている。したがって、損失決定素子176の形状を作製する方法は重要であって、特開平10-56233号には詳細に説明されている。

(5)

7

【0014】その一例を簡単に説明すると、図18

(a)に示すように、湾曲表面を形成しようとする層181の表面にフォトリソスト182を塗布する。次に、図18(b)に示すように、通常の露光、現像、ベーク工程を用いて円筒形フォトリソスト柱183を形成する。このフォトリソスト柱183を、約5〜20分にわたって、約250〜300℃の温度で加熱すると、図18(c)に示すように、凸状の湾曲面を有する形状の層184に変形する。この層184を室温に戻した後も、その凸状の湾曲面の形状を安定に保持している。次に、上方から反応性イオンエッチング(RIE)を用いて、ドライエッチングを施すと、層184がエッチングマスクとして作用して、その形状を反映する結果、図18(d)に示すように、凸状の湾曲面を有する構造185が形成される。

【0015】以上、凸状の湾曲面を有する構造を形成する方法について説明したが、層181上の中央部ではなくて、その周辺部にフォトリソスト柱183を設けるようにすれば、層181上の中央部に凹状の湾曲面を有する構造を形成することができる。

【0016】しかし、エッチングマスクとして作用する層184の形状は、所定の位置において所定の湾曲面を有することが必要とされるが、この湾曲面がいつも同じになるように、再現性よく、また、位置依存性なく、形成することは、現在のエッチング技術によっても相当に困難である。特に、VCSEL素子を多数設けて二次元アレイ化するような場合には、この問題が顕著となる。さらに、所定の湾曲面を有する形状と所定の膜厚を有する損失決定素子176を形成するために、RIE工程においてエッチングマスクとして作用する層184の消失時点または消失後において、適切な位置でエッチングを終了することは著しく困難である。また、VCSEL素子を多数設けて二次元アレイ化するような場合には、同一基板上、または異なる基板上において、フォトリソスト柱183と損失決定素子176を構成している材料間でエッチング選択比を高精度に制御することは非常に困難であり、そのため、各VCSEL素子間で損失決定素子176の反射率特性を揃えることはきわめて困難である。

【0017】以上のように、損失決定素子176の形状や膜厚を、同一基板上の各VCSEL素子間で、または異なる基板上の各VCSEL素子間で、あるいはプロセスのロットが異なる各VCSEL素子間で、バラツキをなくすこと、あるいはバラツキを小さくすることは、きわめて困難である。

【0018】一方、損失決定素子176の凹状の湾曲面の形状を利用して、光軸179から離間するに従って共振器の光学損失を漸進的に増大させ、それによって注入電流値を増大させて、高次横モードのレーザ発振への移行を抑制し、基本横モードのレーザ発振を可能としてい

8

るので、損失決定素子176の凹状の湾曲面の形状が異なれば、高次横モードのレーザ発振へ移行するVCSELの光出力値、すなわち、基本横モードの最大光出力値が異なってくる。その結果、同一基板上の各VCSEL素子間で、または異なる基板上の各VCSEL素子間で、あるいはプロセスのロットが異なる各VCSEL素子間で、各VCSEL素子の基本横モードの最大光出力値が異なることとなり、高輝度基本横モード光出力が要求される用途に対しては、特開平10-56233号に開示された技術を工業的に利用することは困難である。

【0019】そこで、本発明の目的は、位置バラツキが小さく、かつ、再現性よく、しかも、容易に作製することができる高輝度基本横モード光出力を有する面発光レーザおよび面発光レーザアレイを提供することにある。

【0020】

【課題を解決するための手段】本発明者等は、鋭意検討した結果、下記的手段により上記課題が解決できることを見出し本発明を完成するに至った。すなわち、本発明の面発光レーザは、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくともレーザ光の出射前にレーザ光を受ける位置に積層され、レーザ光を反射層の側に反射する第1調整層と、反射層と前記第1調整層とで反射されたレーザ光が入射される透光性の第2調整層とを設けたことを特徴とする。

【0021】本発明の面発光レーザの一例は、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を少なくとも一方の反射層の側に反射する第1調整層と、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されて、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層とを設けたことを特徴とする。

【0022】本発明の面発光レーザの他の一例は、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を少なくとも一方の反射層の側に反射する第1調整層と、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と



(6)

9

第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されて、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層とを設けたことを特徴とする。

【0023】本発明の面発光レーザの他の一例は、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方のスペーサ層とその外側の反射層との間に積層され、レーザ光を少なくとも一方のスペーサ層の側に反射する第1調整層と、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層と第1調整層との間に位置し、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されて、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層とを設けたことを特徴とする。

【0024】本発明の面発光レーザの他の一例は、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方のスペーサ層とその外側の反射層との間に積層され、レーザ光を前記少なくとも一方のスペーサ層の側に反射する第1調整層と、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されて、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層とを設けたことを特徴とする。

【0025】また、本発明の面発光レーザアレイは、本発明の面発光レーザを複数個アレイ状に配列してなることを特徴とする。

【0026】以上のような構成の面発光レーザによれば、基本横モードのレーザ発振の特性を損なうことなく、副次的に発生する高次横モードのレーザ発振を選択的に抑制することができ、基本横モード光出力を高めることができる。さらには、レーザ共振器におけるレーザ光の出射中心の周辺部の実効屈折率が出射中心の実効屈折率よりも低くなるので、レーザ共振器に屈折率導波路構造を形成することができ、基本横モードのレーザ発振を効率的に生じさせることができる。構造的にも、再現性が高く、容易な工程により面発光レーザを作製することができ、高輝度基本横モード光出力が得られる面発光レーザを高い歩留まりで、かつ、安価に提供することができる。

【0027】

【発明の実施の形態】まず、本発明の原理を簡単に説明

10

する。図1(a)は、本発明に係る垂直共振器型面発光レーザ(VCSEL)の構造を簡略化して示した断面図である。このVCSELは、活性層とこの活性層の両側に積層した上部スペーサ層および下部スペーサ層とからなる活性層領域11と、活性層領域11の上部スペーサ層に積層した上部反射層12と、活性層領域11の下部スペーサ層に積層した下部反射層13と、上部反射層12におけるレーザ光の出射中心の周辺部に第1調整層14と第2調整層15とを設けて構成した副次的な共振器とにより構成されている。また、図1においては、第1調整層14が透光性を有していないため、レーザ光の出射領域は第1調整層14で囲まれた領域と一致している。なお、本明細書においては、説明の便宜上、レーザ光が出射する側を上部、その反対側を下部とする。ただし、上部および下部は相対的なものであり、これに限定されることはない。

【0028】この副次的な共振器は、上部反射層12と、第1調整層14と、これらの間に挟まれた透光性の第2調整層15とにより構成され、活性層領域で発生したレーザ光が第2調整層15を通過して第1調整層14で反射され、次に第1調整層14に対向する上部反射層12で再度反射されて第2調整層15に入射するように構成される。このとき、上部反射層12と第1調整層14との間で多重反射が生じ、上部反射層12と第1調整層14との間で反射されたレーザ光は第2調整層15に入射することで位相が変化し、位相変化後のレーザ光と入射したレーザ光とが互いに干渉して、その合成波を減衰させ、反射率が低下すると考えられる。また、位相の変化によりレーザ光の出射領域とその周辺部とで発振波長が変化する場合には、光閉じ込め効果が生じるものと考えられる。第2調整層15の光学的膜厚(材料の誘電率で光速を補正したときの膜厚)を制御することにより副次的な共振器において共振する波長を基本横モードで発振するレーザ光の発振波長(例えば780nm)に等しくすると、レーザ光の発振波長付近における副次的な共振器の反射率が減少し、その結果、レーザ光の出射領域の周辺部におけるレーザ共振器の反射率が局所的に低下することとなる。

【0029】このようにレーザ光の出射領域の周辺部におけるレーザ共振器の反射率が低下すると、図1(b)において破線で示すように、基本横モードでレーザ発振する光の強度が周辺部において小さくなり、また、図1(c)において破線で示すように、高次横モードでレーザ発振する光の強度が周辺部において小さくなる。その結果、基本横モードでレーザ発振する光は出射領域に集中するようになるのに対し、高次横モードでレーザ発振する光は周辺部に集中するようになるため、上部反射層12で反射されるたびごとに、高次横モードでレーザ発振する光の強度は、基本横モードでレーザ発振する光の強度に比べて低くなる。

【0:0 3 5】このように共振波長が領域ごとに異なるものとなると、上記の関係式から、レーザ共振器の実効屈折率も、レーザ光の出射領域とその周辺部において異なるものとなり、第1調整層14および第2調整層15が存在しない領域では $n_0$ 、第1調整層14および第2調整層15が存在する領域では $n_1$ となる。

【0-03-8】〔第1の実施の形態〕図3は、本発明の第1の実施の形態に係る垂直共振器型面発光レーザ（VCSEL）の断面図である。このVCSELは、活性層とこの活性層の両側に積層した上部スペーサ層および下部



(8)

13

スペーサ層とからなる活性層領域11と、この活性層領域11の上部スペーサ層に積層した上部反射層12と、活性層領域11の下部スペーサ層に積層した下部反射層13と、上部反射層12におけるレーザ光の出射中心の周辺部に第1調整層14と第2調整層15とを設けて構成した副次的な共振器とにより構成されている。

【0039】活性層領域11は、アンドープAl<sub>0.5</sub>Ga<sub>0.5</sub>Asからなる下部スペーサ層と、アンドープ量子井戸活性層（膜厚90nmのAl<sub>0.11</sub>Ga<sub>0.89</sub>As量子井戸層3層と膜厚50nmのAl<sub>0.3</sub>Ga<sub>0.7</sub>As障壁層4層とで構成されている）と、アンドープのAl<sub>0.5</sub>Ga<sub>0.5</sub>As上部スペーサ層とで構成され、この活性層領域11の光学的膜厚が媒質内波長（例えば、780nm）となる。

【0040】上部反射層12は、Al<sub>0.9</sub>Ga<sub>0.1</sub>AsとAl<sub>0.3</sub>Ga<sub>0.7</sub>Asとをそれぞれの光学的膜厚がレーザ発振波長（例えば、780nm）に対して1/4波長となるように交互に20周期積層して構成したDBR（多重ブラッグ回折鏡）からなる。

【0041】第2調整層15は、上部反射層12の全面、すなわち、レーザ光の出射中心およびその周辺部の全面に積層した、光学的膜厚がレーザ発振波長（例えば、780nm）に対して1.55/4~1.62/4倍、好ましくは1.6/4倍のAl<sub>0.3</sub>Ga<sub>0.7</sub>Asからなる。

【0042】第1調整層14は、第2調整層15上におけるレーザ光の出射中心の周辺部に積層した膜厚200nmの金により構成されている。ここで、第1調整層14の膜厚を200nmとしたが、100nm程度以上の膜厚があれば、高次横モードの発振を抑制する効果が十分に得られる。

【0043】下部反射層13は、Al<sub>0.9</sub>Ga<sub>0.1</sub>AsとAl<sub>0.3</sub>Ga<sub>0.7</sub>Asとをそれぞれの光学的膜厚がレーザ発振波長（例えば、780nm）に対して1/4波長となるように交互に40.5周期積層して構成したDBR（多重ブラッグ回折鏡）からなる。なお、下部反射層13は、図示しないバッファ層を介して図示しない基板上に積層されている。

【0044】この例の副次的な共振器は、上部反射層12と、第1調整層14と、これらの間に挟まれた第2調整層15とにより構成され、上部反射層12と第1調整層14との間で多重反射によりレーザ光の位相を変化させて、光波の干渉を発生させて、レーザ光の出射中心の周辺部における反射率を低下させるものである。

【0045】図4は、第2調整層15の光学的膜厚とレーザ発振波長780nmにおける振幅反射率との関係を示すグラフである。図4中の実線は、第2調整層15の光学的膜厚を変化させたときの、第1調整層14および第2調整層15が存在するレーザ光の出射中心の周辺部におけるレーザ発振波長780nmにおける振幅反射率

14

の変化を示すものである。図4の実線から分かるように、第2調整層15の光学的膜厚が約 $1.6 \times 1/4$ 波長の時に、振幅反射率は約0.385と最小となる。

【0046】一方、図4中の破線は、第1調整層14を設けないほかは、図3と同様に構成したVCSELにおいて、第2調整層15の光学的膜厚を変化させたときの、第2調整層15が存在するレーザ光の出射中心の周辺部におけるレーザ発振波長780nmにおける振幅反射率の変化を示すものである。図4の破線から分かるように、第2調整層15の光学的膜厚が約 $1.6 \times 1/4$ 波長の時にも、振幅反射率は約0.992と高い状態を維持する。

【0047】図5は、第2調整層15の光学的膜厚が約 $1.6 \times 1/4$ 波長の時における強度反射スペクトルを示すグラフである。図5(a)は、第1調整層14を設けた場合の強度反射スペクトルであり、図5(b)は、第1調整層14を設けなかった場合の強度反射スペクトルである。図5(a)に示すように、第1調整層14および第2調整層15が存在するレーザ光の出射中心の周辺部における上部反射層12の反射スペクトルには、副次的な共振器による反射率および/または実効屈折率の低下効果によりレーザ発振波長780nm付近に反射率の落ち込みが現れる。一方、図5(b)に示すように、第1調整層14を設けなかった場合には、第2調整層15が存在するレーザ光の出射中心の周辺部における上部反射層12の反射スペクトルには、レーザ発振波長780nm付近に反射率の落ち込みは生ぜず、依然として反射率の高い状態を維持している。

【0048】このような特性を利用すれば、第2調整層15を上部反射層12の全面（出射中心およびその周辺部の全面）に積層し、さらに第2調整層15の周辺部に第1調整層14を積層する構成とすることが可能となり、第2調整層15を上部反射層12の周辺部のみに形成する場合に比較して、製作工程が簡便となる利益が得られる。

【0049】また、第2調整層15の光学的膜厚を制御して、副次的な共振器において共振する波長をレーザ光の発振波長（例えば、780nm）よりも短波長側にシフトさせるか、または、レーザ光の出射中心において共振する波長を長波長側にシフトさせることにより、レーザ光の出射中心における実効屈折率に対して、その周辺部における実効屈折率を小さくすることができ、これにより、屈折率導波構造を形成することが可能となる。

【0050】さらには、屈折率導波路の基本横モードおよび高次横モードの光電場の分布条件、ならびに出射中心とその周辺部の反射率差も考慮して、第2調整層15の光学的膜厚を選定することにより、基本横モードレーザ発振特性の良好な屈折率導波路構造を形成することができる。

【0051】〔第2の実施の形態〕図6(a)および

(9)

15

(b)は、それぞれ本発明の第2の実施の形態に係る垂直共振器型面発光レーザ (VCSEL) の断面図である。図6 (a) は、図3に示したVCSELにおいて、上部反射層12に積層した第2調整層15のうちレーザ光の出射中心上に位置する部分を除去した形態としたほかは、同様の構成である。図6 (b) は、図3に示したVCSELにおいて、第2調整層15におけるレーザ光の出射中心上に、さらに、レーザ光の発振波長 (例えば、780nm) に対する反射率を高めるための反射特性補正層16を積層したほかは、同様の構成である。反射特性補正層16は、例えば、二酸化珪素などの誘電体などから構成することができる。図6 (a) および (b) に示した構成例は、いずれも、レーザ光の出射中心における反射率が高くなるように反射特性を改善するものである。

【0052】図7は、上部反射層12の強度反射スペクトルを示すグラフである。図7中の実線は、図6 (a) および (b) の構成例において第1調整層14および第2調整層15を設けなかった場合の上部反射層12の強度反射スペクトルを示し、図7中の破線は、図6 (b) の構成例において第1調整層14および反射特性補正層16を設けなかった場合の上部反射層12の強度反射スペクトルを示す、図5 (b) と同様のスペクトル図である。また、図7のグラフの内部には、レーザ光の発振波長が780nm付近における強度反射スペクトルを拡大して示してある。

【0053】図7から分かるように、レーザ光の発振波長780nm付近における上部反射層12の強度反射率は、第2調整層15を積層しなかった場合の方が、第2調整層15を積層した場合よりも高くなる。このことは、第2調整層15が上部反射層12の反射特性を低下させていることを意味している。

【0054】したがって、図6 (a) に示すように、第2調整層15におけるレーザ光の出射中心上の部分を除去する構成とすれば、レーザ光の出射中心における上部反射層12の反射率をより高くすることができる。また、図6 (b) に示すように、第2調整層15におけるレーザ光の出射中心上の部分にさらに反射特性補正層16を積層することにより、レーザ光の出射中心における上部反射層12の反射率をより高くすることができる。

【0055】また、第2調整層15の光学的膜厚を制御して、副次的な共振器において共振する波長をレーザ光の発振波長 (例えば、780nm) よりも短波長側にシフトさせるか、または、レーザ光の出射中心において共振する波長を長波長側にシフトさせることにより、レーザ光の出射中心における実効屈折率に対して、その周辺部における実効屈折率を小さくすることができ、これにより、屈折率導波構造を形成することが可能となる。

【0056】さらには、屈折率導波路の基本横モードおよび高次横モードの光電場の分布条件、ならびに出射中、

16

心とその周辺部の反射率差も考慮して、第2調整層15の光学的膜厚を選定することにより、基本横モードレーザ発振特性の良好な屈折率導波路構造を形成することができる。

【0057】〔第3の実施の形態〕図8は、本発明の第3の実施の形態に係る垂直共振器型面発光レーザ (VCSEL) の断面図である。この例は、図3に示したVCSELにおいて、第2調整層15を均一の組成とせず、複数の層からなる構成とし、第1調整層14を電極として兼用するようにしたほかは、同様の構成である。第1調整層14は、膜厚200nmの金により形成し、これをVCSELに電流を注入するための一方の電極として兼用する。第2調整層15は、電極として兼用する第1調整層14と半導体層との電気的な接合を良好にするための膜厚20nmのGaAsコンタクト層15Aと、光学的膜厚がレーザ発振波長 (780nm) に対して約  $0.44 \times 1/4$  波長のAl<sub>0.3</sub>Ga<sub>0.7</sub>As層15Bと、光学的膜厚がレーザ発振波長 (780nm) に対して  $1/4$  波長のAl<sub>0.9</sub>Ga<sub>0.1</sub>As層15Cとの3つの層により構成されている。

【0058】このように、第2調整層15を、コンタクト層15Aと、Al<sub>0.3</sub>Ga<sub>0.7</sub>As層15Bと、Al<sub>0.9</sub>Ga<sub>0.1</sub>As層15Cの複数の組成からなる構成とすることにより、電極を兼用する第1調整層14との電気的な接合を十分にとりながら、レーザ光の発振波長780nmにおける振幅反射率は、レーザ光の出射中心の周辺部で約0.705、出射中心で約0.993となり、高輝度基本横モードのレーザ出力を得ることができる。

【0059】以上のように、第2調整層15の構成は、単一の材料からなる構成に限られず、高次横モードのレーザ発振を適切に抑制できるような副次的な共振器を構成できるものであれば、複数の材料からなる多層構成とすることもできる。

【0060】また、第2調整層15の光学的膜厚を制御して、副次的な共振器において共振する波長をレーザ光の発振波長 (例えば、780nm) よりも短波長側にシフトさせるか、または、レーザ光の出射中心において共振する波長を長波長側にシフトさせることにより、レーザ光の出射中心における実効屈折率に対して、その周辺部における実効屈折率を小さくすることができ、これにより、屈折率導波構造を形成することが可能となる。

【0061】さらには、屈折率導波路の基本横モードおよび高次横モードの光電場の分布条件、ならびに出射中心とその周辺部の反射率差も考慮して、第2調整層15の光学的膜厚を選定することにより、基本横モードレーザ発振特性の良好な屈折率導波路構造を形成することができる。

【0062】〔第4の実施の形態〕詳細は後述するが、本発明においては、上部DBR層中のレーザ光の出射中

(10)

17

心の周辺部の一部に、光学的膜厚が媒質内波長の $1/4$ となる第2調整層を挿入し、この第2調整層と、活性層領域のスペーサ層との間に、第1調整層を設ける構成としてもよい。このような構成によっても、上部DBR層中の第2調整層と、活性層領域のスペーサ層との間に位置する第1調整層とにより、その部分におけるレーザ共振器の反射率および/または実効屈折率を低下させることができる。ただし、第2調整層を活性層領域のスペーサ層の直上に挿入した場合には、その部分におけるレーザ共振器の反射率および/または実効屈折率を低下させる効果が十分には得られない。また、第1調整層を上部DBR層の一部を兼用する構成としてもよい。

【0063】〔第5の実施の形態〕詳細は後述するが、本発明においては、VCSELの複数を同一基板上にまたは異なる基板上に配置して、VCSELアレイを構成してもよい。

【0064】以上、本発明の実施の形態を説明したが、本発明を実施するに際しては、第2調整層15を構成する材料としては、特に限定されず、例えば、第2調整層15が活性層に電流を注入する通路となる構成を採用するときは、導電性材料を用いればよく、第2調整層15が活性層に電流を注入する通路とならない構成を採用するときは、半導体や誘電体を用いればよい。また、第1調整層14を構成する材料についても、特に限定されず、例えば、電極を兼用するときは、金などの導電性材料を用いればよく、電極を兼用しないときは、半導体や誘電体を用いることができる。また、単一の材料からなる構成であってもよいし、複数の材料からなる多層構成であってもよい。また、反射特性補正層16を構成する材料についても、二酸化珪素などの誘電体に限定されることはなく、他の誘電体や半導体や金属で構成してもよい。

【0065】

【実施例】以下、本発明の実施例について説明する。

【0066】〔実施例1〕この実施例1は、図3に示した第1の実施の形態に対応するものである。図9(a)に示すように、有機金属気相成長(MOCVD)法により、n型GaAs基板91上に、キャリア濃度が $1 \times 10^{18} \text{ cm}^{-3}$ で膜厚が $0.2 \mu\text{m}$ 程度のn型GaAsバッファ層92を積層する。

【0067】このバッファ層92上に、MOCVD法により、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ とをそれぞれの光学的膜厚が媒質内波長の $1/4$ となるように交互に40.5周期積層して、キャリア濃度が $1 \times 10^{18} \text{ cm}^{-3}$ で総膜厚が約 $4 \mu\text{m}$ の下部n型DBR層93を設ける。

【0068】この下部n型DBR層93上に、MOCVD法により、アンドープ下部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサ層と、アンドープ量子井戸活性層(膜厚 $90 \text{ nm}$ の $\text{Al}_{0.11}\text{Ga}_{0.89}\text{As}$ 量子井戸層3層と、膜厚 $50 \text{ nm}$

18

の $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 障壁層4層とで構成されている)と、アンドープ上部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサ層とにより構成された光学的膜厚が媒質内波長となる活性層領域94を設ける。

【0069】この活性層領域94上に、MOCVD法により、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ とをそれぞれの光学的膜厚が媒質内波長の $1/4$ となるように交互に20周期積層して、キャリア濃度が $1 \times 10^{18} \text{ cm}^{-3}$ で総膜厚が約 $2 \mu\text{m}$ の上部p型DBR層95を設ける。

【0070】この上部p型DBR層95上に、MOCVD法により、キャリア濃度が $1 \times 10^{18} \text{ cm}^{-3}$ で光学的膜厚が媒質内波長の $1.55/4 \sim 1.62/4$ 倍、好ましくは $1.6/4$ 倍のp型 $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 第2調整層96を積層する。

【0071】ここで、図示しないが、キャリア濃度が $1 \times 10^{19} \text{ cm}^{-3}$ で光学的膜厚が $10 \text{ nm}$ 程度のp型GaAsコンタクト層を最上部に積層してもよい。また、詳しくは述べないが、DBR層93および95の電気的抵抗を下げるために、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ との界面に、AlAs組成を90%から30%に段階的に変化した光学的膜厚が $9 \text{ nm}$ 程度の領域を設けてもよい。

【0072】ここで、MOCVD法による成膜においては、原料ガスとしては、トリメチルガリウム、トリメチルアルミニウム、アルシンを用い、ドーパント材料としては、p型用にシクロペンタジニウムマグネシウム、n型用にシランを用い、膜成長時の基板温度は $750^\circ\text{C}$ とし、原料ガスを順次変化させ、連続して成膜を行った。

【0073】続いて、図9(b)に示すように、フォトリソグラフィにより結晶成長層上にレジストマスクRを形成し、四塩化炭素をエッチングガスとして用いた反応性イオンエッチングにより、下部n型DBR層93の途中までエッチングし、径が $10 \sim 30 \mu\text{m}$ 程度の円柱もしくは角柱からなるポストSを形成し、これにより電流狭窄部を形成している。

【0074】レジストRを除去した後、図9(c)に示すように、プラズマCVD装置を用いて、第2調整層96上にSiN層97を蒸着した後、通常フォトリソグラフィ工程とバッファードふっ酸を用いたSiNのエッチングにより、ポストSの上部に位置するSiN層97を剥離する。

【0075】その後、図9(d)に示すように、フォトリソグラフィ工程を用いて、ポストSの上部中央部にレジストパターンTを形成し、その上方からEB蒸着機を用いて、p側電極を兼用する第1調整層を構成することとなるTiとAuをそれぞれ $10 \text{ nm}$ 、 $200 \text{ nm}$ の厚さで蒸着する。

【0076】最後に、アセトンを用いて、レジストパターンTをその上部に蒸着されたTiおよびAuとともに

(11)

19

剥離して、図9(e)に示すように、p側電極を兼用する第1調整層98が第2調整層96におけるレーザ光の出射中心の周辺部に積層された構造のVCSELを得る。

【0077】このVCSELにおいて、p側電極を兼用する第2調整層96が存在しない領域、すなわち、レジストパターンTが存在していた領域であるポストSの中央部からレーザ光が出射されるが、この出射領域の口径は3~20 $\mu\text{m}$ 程度が好ましい。なお、基板91の裏面には、図示しないn側電極としてAuGeが蒸着されてい

る。

【0078】以上のようにして作製したVCSELにおいては、ポストSの中央部のレーザ光の出射中心の直下における共振器反射率は約99.5%と高く、また、p側電極を兼用する第1調整層98の直下における共振器反射率は、図4に示した結果と同様に低くなり、高次横モードのレーザ発振を適切に抑制することができた。その結果、従来の技術では基本横モードのレーザ発振を得るためにはレーザ光の出射領域の口径は5 $\mu\text{m}$ 以下とすることが必要とされたが、本発明によれば、出射領域の口径を5 $\mu\text{m}$ 以上としても、基本横モードのレーザ発振が可能となり、高輝度基本横モード光出力を得ることができる。

【0079】この実施例1に係るVCSELの基本横モードのレーザ発振および高次横モードのレーザ発振と、図17に示した従来のVCSELの基本横モードのレーザ発振および高次横モードのレーザ発振を調べたところ、図10に示す結果が得られた。すなわち、活性層への注入電流を増加させた場合に、実施例1に係るVCSELおよび従来のVCSELともに、高次横モードのレーザ発振は抑制され、基本横モードだけが発振するが、実施例1のVCSELに比べて、従来のVCSELでは、基本横モードのレーザ発振を開始する電流のしきい値および効率がともに低下していることが分かる。

【0080】この実施例1では、第2調整層96は、Al<sub>0.3</sub>Ga<sub>0.7</sub>Asを用いて構成したが、第1調整層98の直下におけるレーザ共振器の反射率および/または実効屈折率を低下させることができる材料であれば、他の材料を用いて構成することもできる。ただし、この実施例1のように、第2調整層96が注入電流の通路を構成する場合には、導電型材料であって、電流の注入が容易な材料を用いるのが好ましい。

【0081】また、この実施例1では、下部n型DBR層93の途中までエッチングしてポストSを形成しているが、上部Al<sub>0.5</sub>Ga<sub>0.5</sub>Asスペーサー層あるいは、それより上方でエッチングを停止してポストSを形成してもよいし、また、基板91の直上までエッチングしてポストSを形成してもよい。

【0082】また、この実施例1では、活性層の材料としてAlGaAsを用いたが、GaAsまたはInGa

20

Asを用いて近赤外用のVCSELを構成することもできるし、また、InGaPまたはAlGaInPを用いて赤色用のVCSELを構成することもできる。さらには、GaN系やZnSe系等を用いて青色または紫外線用のVCSELや、InGaAsP系等を用いて1.3~1.5 $\mu\text{m}$ 帯用のVCSELも構成することができる。

【0083】また、DBR層93および95の材料としては、半導体材料に限定されることはなく、種々の電流注入方式を選択することにより、絶縁膜を用いることもできる。DBR層93および95の材料として絶縁膜を用いる場合には、第2調整層96の材料としても、半導体よりは絶縁膜を用いるのが好ましい。

【0084】〔実施例2〕この実施例2は、図6(a)に示した第2の実施の形態に対応するものである。図11に示すように、MOCVD法により、n型GaAs基板91上に、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で膜厚が0.2 $\mu\text{m}$ 程度のn型GaAsバッファ層92を積層する。

【0085】このバッファ層92上に、MOCVD法により、Al<sub>0.9</sub>Ga<sub>0.1</sub>AsとAl<sub>0.3</sub>Ga<sub>0.7</sub>Asとをそれぞれの光学的膜厚が媒質内波長の1/4となるように交互に40.5周期積層して、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で総膜厚が約4 $\mu\text{m}$ の下部n型DBR層93を設ける。

【0086】この下部n型DBR層93上に、MOCVD法により、アンドープ下部Al<sub>0.5</sub>Ga<sub>0.5</sub>Asスペーサー層と、アンドープ量子井戸活性層(膜厚90nmのAl<sub>0.11</sub>Ga<sub>0.89</sub>As量子井戸層3層と、膜厚50nmのAl<sub>0.3</sub>Ga<sub>0.1</sub>As障壁層4層とで構成されている)と、アンドープ上部Al<sub>0.5</sub>Ga<sub>0.5</sub>Asスペーサー層とで構成された光学的膜厚が媒質内波長となる活性層領域94を設ける。

【0087】この活性層領域94上に、MOCVD法により、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で光学的膜厚が媒質内波長の1/4となるp型AlAs層99を設ける。このp型AlAs層99上に、Al<sub>0.9</sub>Ga<sub>0.1</sub>AsとAl<sub>0.3</sub>Ga<sub>0.7</sub>Asとをそれぞれの光学的膜厚が媒質内波長の1/4となるように交互に19.5周期積層して、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で総膜厚が約2 $\mu\text{m}$ の上部p型DBR層95を設ける。

【0088】この上部p型DBR層95上に、MOCVD法により、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で光学的膜厚が媒質内波長の1.55/4~1.62/4倍、好ましくは1.6/4倍のp型In<sub>0.5</sub>Ga<sub>0.5</sub>P第2調整層96を設ける。

【0089】ここで、図示しないが、キャリア濃度が $1 \times 10^{19} \text{cm}^{-3}$ で光学的膜厚が1.0nm程度のp型GaAsコンタクト層を最上部に積層してもよい。また、詳しくは述べないが、DBR層93および95の電氣的抵

(12)

21

抗を下げるために、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.1}\text{As}$ との界面に、 $\text{AlAs}$ 組成を90%から30%に段階的に変化させた光学的膜厚が9nm程度の領域を設けてもよい。

【0090】ここで、MOCVD法による成膜においては、原料ガスとしては、トリメチルガリウム、トリメチルアルミニウム、トリメチルインジウム、アルシン、フォスフィンを用い、ドーパント材料としては、p型用にシクロペンタジニウムマグネシウム、n型用にシランを用い、膜成長時の基板温度は750℃とし、真空を破ることなく、原料ガスを順次変化させ、連続して成膜を行った。

【0091】次に、実施例1と同様にして、径が約30μmの円柱状または角錐状のポストSを形成する。その後、約400℃の炉中で水蒸気により $\text{AlAs}$ 層99だけを側方から酸化して高抵抗化させ、これにより電流狭窄部を形成している。この時、非酸化領域が活性層への電流注入領域となるが、その径は約3~20μmである。

【0092】次に、実施例1と同様にして、 $\text{SiN}$ 層（絶縁膜）97、p側電極を兼用する第1調整層98を設ける。その後、通常的光リソグラフィ工程と、燐酸・塩酸・水で構成されたエッチャントによるウエットエッチングにより、 $\text{In}_{0.5}\text{Ga}_{0.5}\text{P}$ 第2調整層96のうちポストSの上部中央部に位置する部分を削除して、図11に示したように、レーザ光の出射中心の周辺部においてp側電極を兼用する第1調整層98および第2調整層96が積層された構造のVCSELを得る。

【0093】この実施例2に係るVCSELは、第2の実施の形態でも説明したように、高次横モードのレーザ発振を抑制し、高輝度基本横モードのレーザ発振を得ることができる。

【0094】また、この実施例2では、第2調整層96のうちポストSの上部中央部における部分を削除しているが、第2の実施の形態でも説明したように、削除する代わりに、ポストSの上部中央部における第2調整層96上に反射特性補正層を積層しても、同様の効果を得ることができる。

【0095】また、この実施例2では、第2調整層96の材料として、選択エッチングが容易にできる $\text{In}_{0.5}\text{Ga}_{0.5}\text{P}$ 層を用いたが、実施例1と同様に、レーザ光の出射中心の周辺部におけるレーザ共振器の反射率および/または実効屈折率を低下させることができるのであれば、他の材料を用いることもできる。

【0096】また、この実施例2においても、実施例1と同様に、活性層の材料として $\text{AlGaAs}$ を用いたが、 $\text{GaAs}$ または $\text{InGaAs}$ を用いて近赤外用のVCSELを構成することもできるし、また、 $\text{InGaP}$ または $\text{AlGaInP}$ を用いて赤色用のVCSELを構成することもできる。さらには、 $\text{GaN}$ 系や $\text{ZnSe}$ 系

22

等を用いて青色または紫外線用のVCSELや、 $\text{InGaAsP}$ 系等を用いて1.3~1.5μm帯用のVCSELも構成することができる。

【0097】〔実施例3〕この実施例3は、図8に示した第3の実施の形態に対応するものである。図12に示すように、上部DBR層95上には、3層から構成された第2調整層96が設けられている。すなわち、この第2調整層96は、上部DBR層95上に設けたキャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で光学的膜厚が媒質内波長の $1/4$ となるp型 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ 層96Cと、この層96C上に設けたキャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で光学的膜厚が媒質内波長の $0.44 \times 1/4$ 倍となるp型 $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 層96Bと、この層96B上に設けたキャリア濃度が $1 \times 10^{19} \text{cm}^{-3}$ で光学的膜厚が20nmのp型 $\text{GaAs}$ コンタクト層96Aとからなる。

【0098】また、この実施例3では、実施例1のようなポストSを形成せずに、上部DBR層95の側部にプロトンを打ち込んで高抵抗領域100を形成し、これにより電流狭窄部を形成している。

【0099】また、第2調整層96上の周辺部には、実施例1と同様にして、 $\text{Ti}$ と $\text{Au}$ とを蒸着してp側電極を兼用する第1調整層98を設けている。この第1調整層98の中央部開口がレーザ光の出射領域となる。

【0100】レーザ光の出射領域の中心と、プロトンを打ち込んで形成した電流狭窄部の中心は、レーザ光の光軸にできるだけ一致することが望ましい。なお、その他の構成は、実施例1と同様であり、その説明は省略する。

【0101】以上のようにして作製したVCSELにおいては、中央部のレーザ光の出射中心の直下における共振器反射率は約99.5%と高く、また、p側電極を兼用する第1調整層98の直下における共振器反射率は約70%と低くなり、高次横モードのレーザ発振を適切に抑制することができた。

【0102】なお、実施例2と同様に、レーザ光の出射中心に位置する第2調整層96の部分をエッチングにより除去するようにしてもよい。また、エッチングにより除去する代わりに、第2の実施の形態でも説明したように、中央部における第2調整層96上に反射特性補正層を積層してもよい。また、この実施例3においても、実施例1と同様に、活性層の材料として $\text{AlGaAs}$ を用いたが、 $\text{GaAs}$ または $\text{InGaAs}$ を用いて近赤外用のVCSELを構成することもできるし、また、 $\text{InGaP}$ または $\text{AlGaInP}$ を用いて赤色用のVCSELを構成することもできる。さらには、 $\text{GaN}$ 系や $\text{ZnSe}$ 系等を用いて青色または紫外線用のVCSELや、 $\text{InGaAsP}$ 系等を用いて1.3~1.5μm帯用のVCSELも構成することができる。

【0103】〔実施例4〕図13に示すように、n型G



(13)

23

aAs基板91上に、MOCVD法により、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で膜厚が $0.2 \mu\text{m}$ 程度のn型GaAsバッファ層92を積層する。

【0104】このバッファ層92上に、MOCVD法により、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ とをそれぞれの光学的膜厚が媒質内波長の $1/4$ となるように交互に40:5周期積層して、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で総膜厚が約 $4 \mu\text{m}$ の下部n型DBR層93を設ける。

【0105】この下部n型DBR層93上に、MOCVD法により、アンドープ下部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサー層と、アンドープ量子井戸活性層(膜厚 $90 \text{nm}$ の $\text{Al}_{0.11}\text{Ga}_{0.89}\text{As}$ 量子井戸層3層と、膜厚 $50 \text{nm}$ の $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 障壁層4層とで構成されている)と、アンドープ上部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサー層とにより構成された膜厚が媒質内波長となる活性層領域94を設ける。

【0106】この活性層領域94上に、MOCVD法により、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ とをそれぞれの光学的膜厚が媒質内波長の $1/4$ となるように交互に20周期積層して、キャリア濃度が $1 \times 10^{18} \text{cm}^{-3}$ で総膜厚が約 $2 \mu\text{m}$ の上部p型DBR層95を設ける。

【0107】この上部p型DBR層95中の周辺部の一部には、アンドープで光学的膜厚が媒質内波長の $1/4$ となる $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 第2調整層96が挿入されている。この $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 第2調整層96は、その下の上部p型DBR層95の一部である $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ が交互に5周期積層されている位置に設けられている。

【0108】この実施例4では、この5周期積層された $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 層が、第2調整層96と活性層領域94のアンドープ上部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサー層との間に位置されることによって、第1調整層98の機能を発揮する。すなわち、この5周期積層された $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 層(第1調整層98)とその直上に位置される第2調整層96とDBR層95とにより、その部分におけるレーザ共振器の反射率および実効屈折率が低下することとなる。

【0109】なお、第2調整層96を活性層領域94のアンドープ上部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサー層の直上に挿入した場合には、その部分におけるレーザ共振器の反射率および実効屈折率を低下させる効果が十分には得られない。

【0110】ここで、図示しないが、キャリア濃度が $1 \times 10^{19} \text{cm}^{-3}$ で膜厚が $10 \text{nm}$ 程度のp型GaAsコンタクト層を最上部に積層してもよい。また、詳しくは述べないが、DBR層93および95の電氣的抵抗を下げるために、 $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}$

24

Asとの界面に、AlAs組成を90%から30%に段階的に変化させた膜厚が $9 \text{nm}$ 程度の領域を設けてもよい。

【0111】この実施例4においても、実施例1と同様に、下部n型DBR層93の途中までエッチングし、径が $10 \sim 30 \mu\text{m}$ 程度の円柱もしくは角柱からなるポストSを形成し、これにより電流狭窄部を形成している。ポストSの周辺とポストSの底部には、SiN層97が蒸着されている。また、ポストSの上部には、TiとAuがそれぞれ $10 \text{nm}$ 、 $300 \text{nm}$ の厚さで蒸着されてp側電極101が形成され、その中央部は除去されている。基板91の裏面には、図示しないが、n側電極としてAuGeが蒸着されている。p側電極101の存在しない部分、すなわち、ポストSの中央部のレーザ光の出射領域からレーザ光が出射されるが、この出射領域の口径は $3 \sim 20 \mu\text{m}$ ぐらいが好ましい。

【0112】この実施例4では、p型DBR層95中に挿入された $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ 第2調整層96と、第1調整層として機能する第2調整層96の直下にある5周期積層された $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}$ と $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ とが形成されていることにより、ポストSの中央部のレーザ光の出射中心の直下における共振器反射率は約99.5%と高く、また、第2調整層96の直下における共振器反射率は、図4に示した結果と同様に低くなり、高次横モードのレーザ発振を適切に抑制することができた。

【0113】この実施例4では、第2調整層96は、 $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ を用いて構成したが、第2調整層96の直下におけるレーザ共振器の反射率および/または実効屈折率を低下させることができる材料であれば、他の材料を用いて構成することもできる。また、第2調整層96として、アンドープ層を用いたが、n型またはp型層を用いることもできる。アンドープ層またはn型層を用いた場合には、第2調整層96自体が、電流狭窄機能をも発揮する利点が得られる。第1調整層98についても、実施例1等と同様に、他の材料を用いて構成することもできる。

【0114】また、この実施例4では、下部n型DBR層93の途中までエッチングしてポストSを形成しているが、上部 $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ スペーサー層あるいはそれより上方でエッチングを停止してポストSを形成してもよいし、また、基板91の直上までエッチングしてポストSを形成してもよい。

【0115】また、この実施例4では、活性層の材料としてAlGaAsを用いたが、GaAsまたはInGaAsを用いて近赤外用のVCSELを構成することもできるし、また、InGaPまたはAlGaInPを用いて赤色用のVCSELを構成することもできる。さらに、GaN系やZnSe系等を用いて青色または紫外線用のVCSELや、InGaAsP系等を用いて1.3

(14)

25

～1.5  $\mu\text{m}$ 帯用のVCSELも構成することができる。

【0116】また、DBR層93および95の材料としては、半導体材料に限定されることはなく、種々の電流注入方式を選択することにより、絶縁膜を用いることもできる。DBR層93および95の材料として絶縁膜を用いる場合には、第2調整層96の材料としても、半導体よりは絶縁膜を用いるのが好ましい。

【0117】また、この実施例4では、p型DBR層95の上面が平坦な例を示したが、再成長技術を用いて第2調整層96を設けた場合などは、図14に示すように、その分だけp型DBR95の上面に凹凸が発生することもあるが、この場合でも同様の効果を得ることができる。

【0118】〔実施例5〕実施例5は、図15に示すように、実施例1で示した構造と同一の構造のVCSEL素子150を同一基板上に複数個配置して、VCSELアレイを構成したものである。この実施例5においては、各VCSEL素子150を互いに電氣的に分離するために、VCSEL素子150間に溝151を設けている。図15においては一方向の断面だけを示しているが、奥行き方向においても溝151により電氣的に分離されている。

【0119】なお、この実施例5においては、電氣的な分離手段として溝151を利用しているが、イオン打ち込みにより高抵抗領域を設ける方法などの他の手段を利用することもできる。

【0120】また、VCSELアレイを構成する各VCSEL素子150としては、実施例1に示したポスト型のものを用いているが、実施例2の選択酸化型や、実施例3のイオン注入型のものを用いることもできる。

【0121】また、VCSELアレイの配置方法は、2次元のみならず、1次元でも差し支えない。各VCSEL素子150の駆動は、独立駆動型でもよいし、マトリックス駆動型でもよく、さらには、同時駆動型でもよい。

【0122】各VCSEL素子150の作製においては、面内均一性に優れた成膜手段を用いているため、VCSELアレイが大規模となっても、各VCSEL素子150間の特性バラツキは非常に小さくなる利点を有している。

【0123】以上の実施例においては、第1の実施の形態とポスト型VCSELとを組み合わせたものを実施例1とし、第2の実施の形態と電流狭窄構造としてAlAs選択酸化型VCSELとを組み合わせたものを実施例2とし、第3の実施の形態と電流狭窄構造としてプロトンインプラ型VCSELとを組み合わせたものを実施例3としたが、これらの組み合わせに限定されることはなく、組み合わせを適宜変更しても、本発明の目的を達成することができる。

26

【0124】

【発明の効果】以上説明したように、本発明によれば、高輝度基本横モード光出力を有するVCSELおよびVCSELアレイを再現性よく、高い歩留りで、かつ、安価に製造することができる。したがって、プリンタ装置、光磁気ディスク装置等、高輝度基本横モード光出力が要求される用途にも、本発明に係るVCSELおよびVCSELアレイを十分に利用することができる。

【図面の簡単な説明】

【図1】(a)は、本発明に係るVCSELの構造を簡略化して示す断面図、(b)は基本横モードでレーザ発振するときの光強度分布を示すグラフ、(c)は高次横モードでレーザ発振するときの光強度分布を示すグラフである。

【図2】本発明に係るVCSELであって、屈折率導波路構造を有するものの断面図である。

【図3】本発明の第1の実施の形態に係るVCSELの断面図である。

【図4】第2調整層の光学的膜厚とレーザ発振波長780nmにおける振幅反射率との関係を示すグラフである。

【図5】第2調整層の光学的膜厚が約 $1.6 \times 1/4$ 波長の時における強度反射スペクトルを示すグラフであり、(a)が本発明の実施の形態に係るものであり、(b)が第1調整層を設けない場合のものである。

【図6】(a)および(b)は、それぞれ本発明の第2の実施の形態に係るVCSELの断面図である。

【図7】上部反射層の強度反射スペクトルを示すグラフである。

【図8】本発明の第3の実施の形態に係るVCSELの断面図である。

【図9】(a)から(e)は、本発明の実施例1に係るVCSELの製造工程を順番に示す断面図である。

【図10】本発明の実施例1に係るVCSELおよび従来のVCSELにおける光出力と注入電流との関係を示すグラフである。

【図11】本発明の実施例2に係るVCSELの断面図である。

【図12】本発明の実施例3に係るVCSELの断面図である。

【図13】本発明の実施例4に係るVCSELの断面図である。

【図14】本発明の実施例4に係るVCSELの断面図である。

【図15】本発明の実施例5に係るVCSELアレイの断面図である。

【図16】従来のプロトンインプラ型のVCSELの断面図である。

【図17】凹状の形状の損失決定素子を有する従来のVCSELの断面図である。

(15)

27

【図18】損失決定素子を有する従来のVCSELにおける損失決定素子の製造工程を順番に示す断面図である。

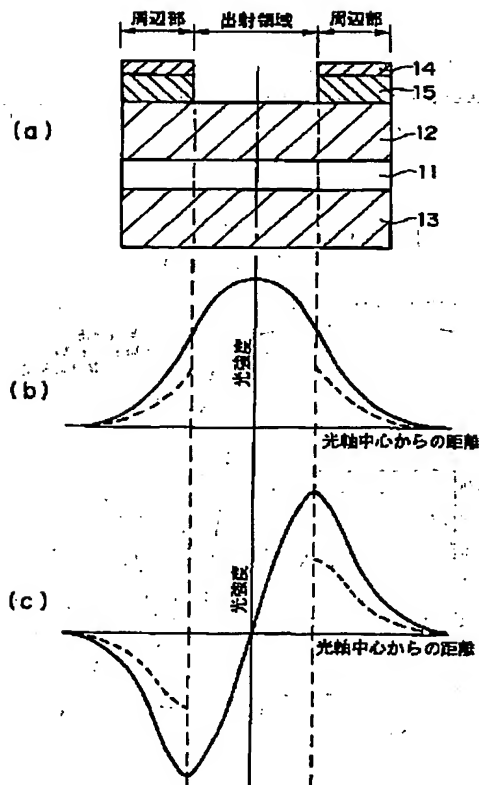
【符号の説明】

- 1 1 活性層領域
- 1 2 上部反射層
- 1 3 下部反射層
- 1 4 第1調整層
- 1 5 第2調整層
- 1 6 反射特性補正層
- 9 1 n型GaAs基板
- 9 2 n型GaAsバッファ層
- 9 3 下部n型DBR層
- 9 4 活性層領域
- 9 5 上部p型DBR層
- 9 6 第2調整層
- 9 7 SiN層
- 9 8 第1調整層
- S ポスト
- R レジスト
- T レジストパターン
- 9 9 p型AlAs層
- 1 0 0 高抵抗領域

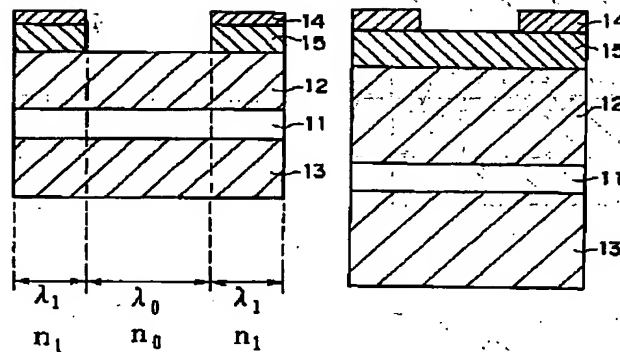
28

- 1 0 1 p側電極
- 1 5 0 VCSEL
- 1 5 1 溝
- 1 6 1 下部n型DBR層
- 1 6 2 活性層領域
- 1 6 3 上部p型DBR層
- 1 6 4 p側電極
- 1 6 5 高抵抗領域
- 1 6 6 出射領域
- 1 7 1 導電型半導体基板
- 1 7 2 下部DBR層
- 1 7 3 活性層領域
- 1 7 4 上部DBR層
- 1 7 5 低反射率ゾーン
- 1 7 6 損失決定素子
- 1 7 7、1 7 8 電極
- 1 7 9 光軸
- 1 8 1 湾曲表面を形成しようとする層
- 1 8 2 フォトレジスト
- 1 8 3 円筒形フォトレジスト柱
- 1 8 4 凸状の湾曲面を有する形状の層
- 1 8 5 凸状の湾曲面を有する構造

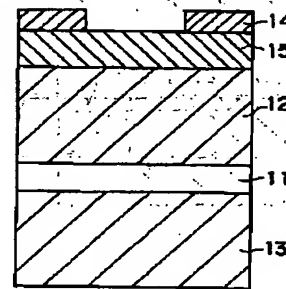
【図1】



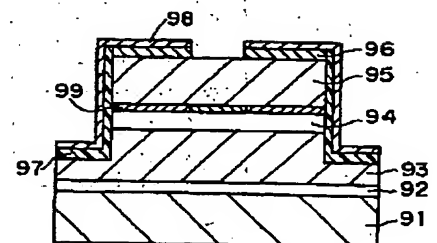
【図2】



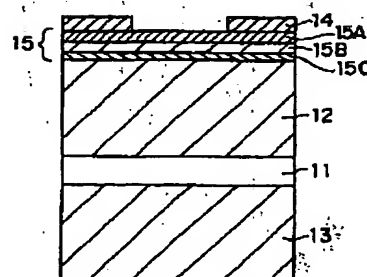
【図3】



【図11】



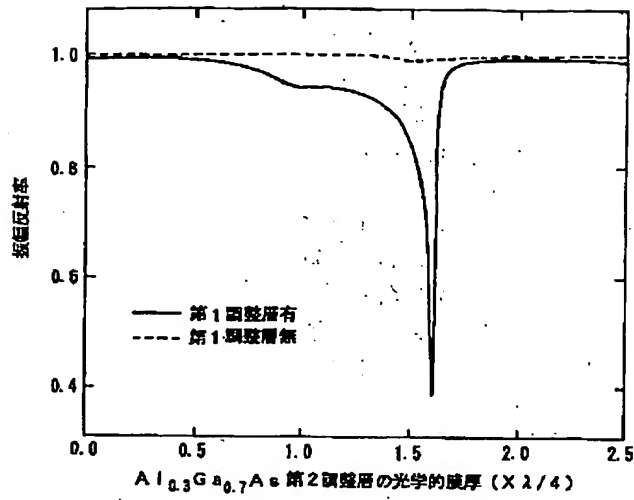
【図8】



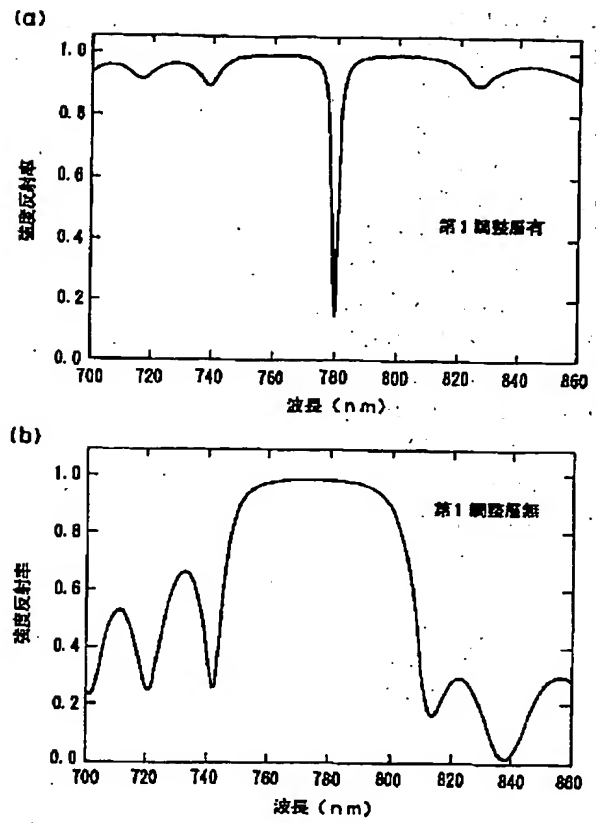


(16)

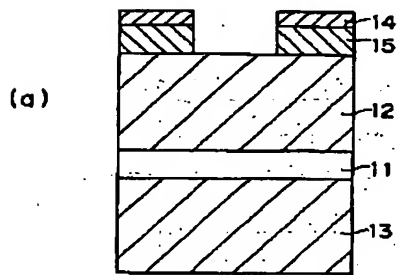
【図4】



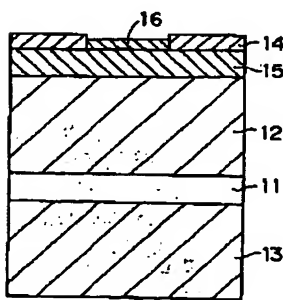
【図5】



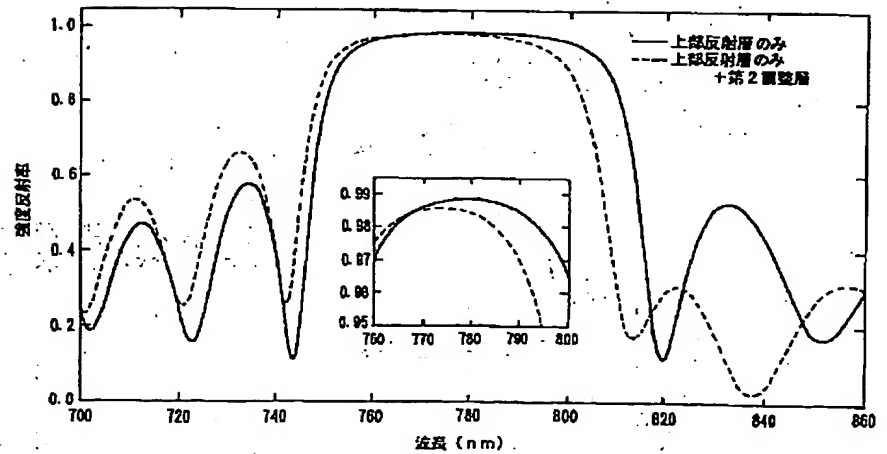
【図6】



(b)

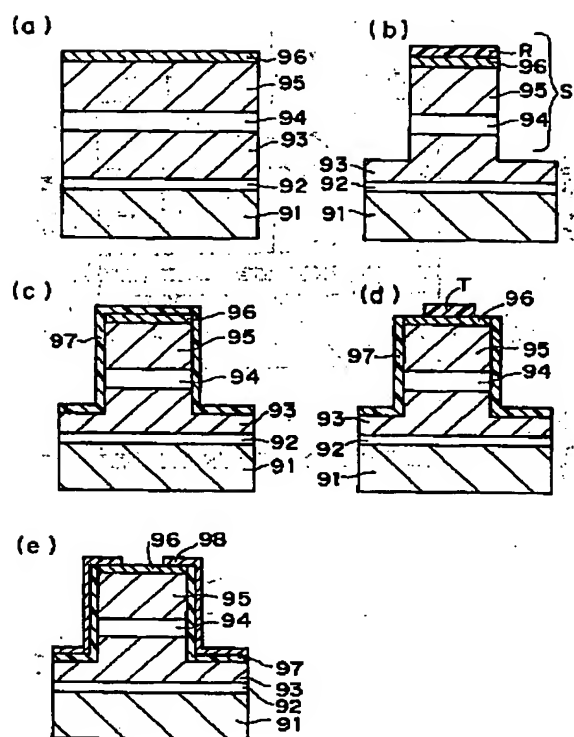


【図7】

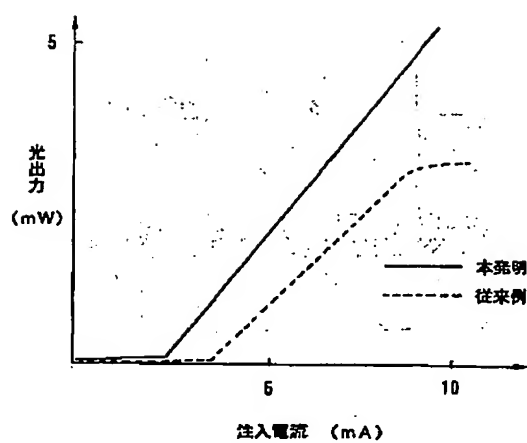


(17)

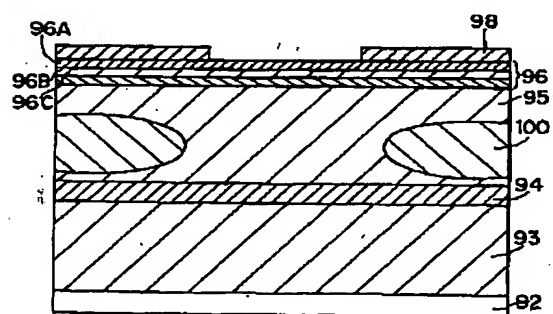
【図9】



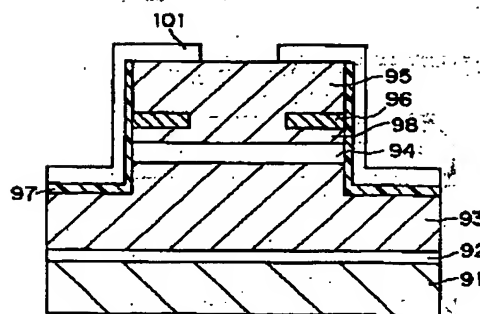
【図10】



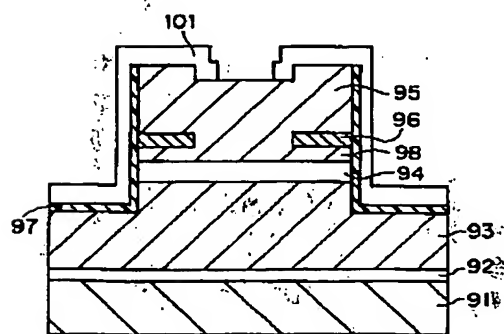
【図12】



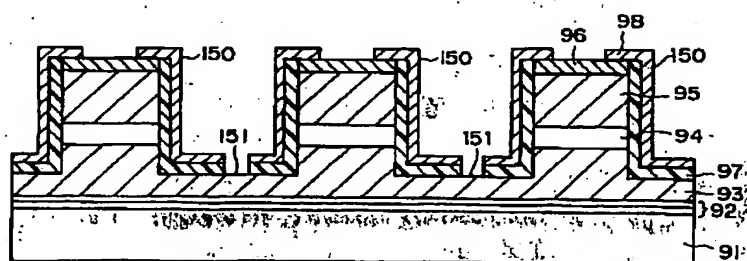
【図13】



【図14】

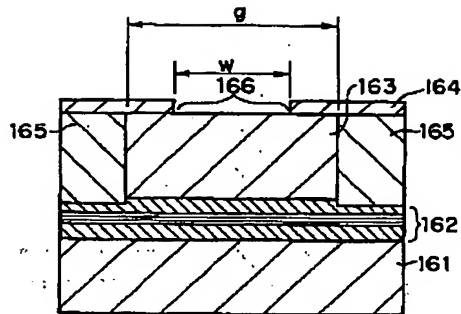


【図15】

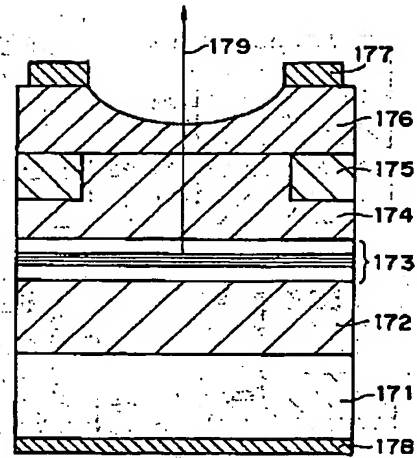


(18)

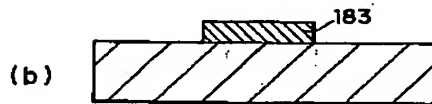
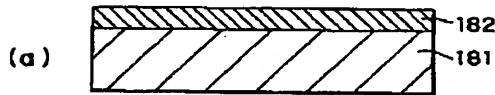
【図16】



【図17】



【図18】



フロントページの続き

(72)発明者 中村 毅  
 神奈川県足柄上郡中井町境430 グリーン  
 テクなかい、富士ゼロックス株式会社内  
 (72)発明者 小山 二三夫  
 神奈川県横浜市緑区長津田4259番地 東京  
 工業大学内

Fターム(参考) 5F073 AA07 AA08 AA51 AA62 AA65  
 AA74 AB04 AB17 BA02 BA06  
 BA07 CA04 CA05 CA06 CA07  
 CA12 CA14 CA22 DA05 DA27  
 EA18

【公報種別】特許法第17条の2の規定による補正の掲載

【部門区分】第7部門第2区分

【発行日】平成15年2月14日(2003.2.14)

【公開番号】特開2000-22271(P2000-22271A)

【公開日】平成12年1月21日(2000.1.21)

【年通号数】公開特許公報12-223

【出願番号】特願平10-190701

【国際特許分類第7版】

H01S 5/30

【FI】

H01S 3/18

【手続補正書】

【提出日】平成14年11月7日(2002.11.7)

【手続補正1】

【補正対象書類名】明細書

【補正対象項目名】特許請求の範囲

【補正方法】変更

【補正内容】

【特許請求の範囲】

【請求項1】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、  
前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくともレーザ光の出射前にレーザ光を受ける位置に積層され、レーザ光を前記反射層の側に反射する第1調整層と、  
前記反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、前記反射層と前記第1調整層とで反射されたレーザ光の位相を変化させる透光性の第2調整層と、  
を設けたことを特徴とする面発光レーザ。

【請求項2】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、  
前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくともレーザ光の出射前にレーザ光を受ける位置に積層され、レーザ光を前記反射層の側に反射する第1調整層と、  
前記反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、入射したレーザ光を前記反射層と前記第1調整層との間で多重反射させる透光性の第2調整層と、  
を設けたことを特徴とする面発光レーザ。

【請求項3】 前記第2調整層の膜厚は、基本横モードでレーザ発振する膜厚であることを特徴とする請求項1

又は2記載の面発光レーザ。

【請求項4】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前記第1調整層との間に積層され、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、位相変化後のレーザ光と入射したレーザ光との合成波を減衰させることにより、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層と、

を設けたことを特徴とする面発光レーザ。

【請求項5】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前記第1調整層との間に積層され、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、前記第1調整層と当該第2調整層と前記反射層とによって多重反射による干渉を発生させて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層と、

(2)

1

と、

を設けたことを特徴とする面発光レーザ。

【請求項6】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前記第1調整層との間に積層され、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長を前記レーザ光の出射中心におけるレーザ光の発振波長とは異なるものにして、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層と、  
を設けたことを特徴とする面発光レーザ。

【請求項7】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前記第1調整層との間に積層され、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、前記第1調整層と当該第2調整層と前記反射層とによって多重反射による干渉を発生させて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層と、

を設けたことを特徴とする面発光レーザ。

【請求項8】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を前記少なくとも一方の反射層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、前記少なくとも一方の反射層と前

2

記第1調整層との間に積層され、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、前記第1調整層と当該第2調整層と前記反射層とによって共振する波長をレーザ光の発振波長よりも短波長側にシフトさせると共に、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層と、  
を設けたことを特徴とする面発光レーザ。

10 【請求項9】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方のスペーサ層とその外側の反射層との間に積層され、レーザ光を前記少なくとも一方のスペーサ層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、前記少なくとも一方の反射層と第1調整層との間に位置し、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層と、  
を設けたことを特徴とする面発光レーザ。

【請求項10】 前記第2調整層は、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、位相変化後のレーザ光と入射したレーザ光との合成波を減衰させることを特徴とする請求項9記載の面発光レーザ。

30 【請求項1.1】 活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方のスペーサ層とその外側の反射層との間に積層され、レーザ光を前記少なくとも一方のスペーサ層の側に反射する第1調整層と、

前記活性層領域で発生したレーザ光の出射中心の周辺部であって、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光が入射されて、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層と、  
を設けたことを特徴とする面発光レーザ。

【請求項12】 前記第2調整層は、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長を前記レーザ光の出射中心におけるレーザ光の発振波長とは異なるものにしたことを特徴とする請求項1.1記載の面発光レーザ。

50 【請求項13】 前記第1調整層は、前記反射層の一部を兼用して構成したことを特徴とする請求項9乃至12

(3)

3

のいずれか1項記載の面発光レーザ。

【請求項14】 前記第2調整層の光学的膜厚がレーザ光の出射中心に位置する部分とその周辺部に位置する部分とで異なり、レーザ光の出射中心におけるレーザ光の発振波長に対する反射率を高くしたことを特徴とする請求項1乃至13のいずれか1項記載の面発光レーザ。

【請求項15】 前記第2調整層におけるレーザ光の出射中心に位置する部分の少なくとも一部に、レーザ光の出射中心におけるレーザ光の発振波長に対する反射率を高くする反射特性補正層を設けたことを特徴とする請求項1乃至14のいずれか1項記載の面発光レーザ。

【請求項16】 前記第2調整層は、1種類または2種類以上の材料または組成からなることを特徴とする請求項1乃至15のいずれか1項記載の面発光レーザ。

【請求項17】 前記第1調整層は、1種類または2種類以上の材料または組成からなることを特徴とする請求項1乃至15のいずれか1項記載の面発光レーザ。

【請求項18】 前記第1調整層は、金属で構成され、一方の電極を兼用することを特徴とする請求項1乃至8のいずれか1項記載の面発光レーザ。

【請求項19】 前記第1調整層は、半導体多層膜で構成されたことを特徴とする請求項1乃至17のいずれか1項記載の面発光レーザ。

【請求項20】 前記第1調整層は、誘電体多層膜で構成されたことを特徴とする請求項1乃至17のいずれか1項記載の面発光レーザ。

【請求項21】 電流狭窄構造がポスト型であることを特徴とする請求項1乃至20のいずれか1項記載の面発光レーザ。

【請求項22】 電流狭窄構造が選択酸化型であることを特徴とする請求項1乃至20のいずれか1項記載の面発光レーザ。

【請求項23】 電流狭窄構造がプロトン打ち込み型であることを特徴とする請求項1乃至20のいずれか1項記載の面発光レーザ。

【請求項24】 請求項1乃至23のいずれか1項記載の面発光レーザを複数個アレイ状に配列してなることを特徴とする面発光レーザアレイ。

【手続補正2】

【補正対象書類名】明細書

【補正対象項目名】0020

【補正方法】変更

【補正内容】

【0020】

【課題を解決するための手段】本発明者等は、鋭意検討した結果、下記的手段により上記課題が解決できることを見出し本発明を完成するに至った。すなわち、本発明の面発光レーザは、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてな

4

る面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくともレーザ光の出射前にレーザ光を受ける位置に積層され、レーザ光を反射層の側に反射する第1調整層と、反射層と前記第1調整層とで反射されたレーザ光が入射されると共に、反射層と第1調整層とで反射されたレーザ光の位相を変化させる透光性の第2調整層と、を設けたことを特徴とする。また、第2調整層は、反射層と第1調整層とで反射されたレーザ光が入射されると共に、入射したレーザ光を前記反射層と前記第1調整層との間で多重反射させる透光性の第2調整層であってもよい。これら第2調整層の膜厚は、基本横モードでレーザ発振する膜厚であることが好ましい。

【手続補正3】

【補正対象書類名】明細書

【補正対象項目名】0021

【補正方法】変更

【補正内容】

【0021】本発明の面発光レーザの一例は、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を少なくとも一方の反射層の側に反射する第1調整層と、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されると共に、少なくとも一方の反射層と第1調整層とで反射されたレーザ光の位相を変化させ、位相変化後のレーザ光と入射したレーザ光との合成波を減衰させることにより、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層とを設けたことを特徴とする。第2調整層は、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されると共に、少なくとも一方の反射層と第1調整層とで反射されたレーザ光の位相を変化させ、位相変化後のレーザ光と入射したレーザ光との合成波を減衰させることにより、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層とすることができる。また、第2調整層は、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されると共に、第1調整層と第2調整層と反射層とによって多重反射による干渉を発生させて、レーザ光の出射中心の周辺

(4)

5

部におけるレーザ光の発振波長に対する反射率を低下させる透光性の第2調整層としてもよい。

【手続補正4】

【補正対象書類名】明細書

【補正対象項目名】0022

【補正方法】変更

【補正内容】

【0022】本発明の面発光レーザの他の一例は、活性層とこの活性層の両側にそれぞれ積層したスペーサ層とからなる活性層領域と、この活性層領域の両側にそれぞれ積層した反射層とを備えてなる面発光レーザにおいて、活性層領域で発生したレーザ光の出射中心の周辺部であって、少なくとも一方の反射層の外側に積層され、レーザ光を少なくとも一方の反射層の側に反射する第1調整層と、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されると共に、前記少なくとも一方の反射層と前記第1調整層とで反射されたレーザ光の位相を変化させ、前記レーザ光の出射中心の周辺部におけるレーザ光の発振波長を前記レ

6

ーザ光の出射中心におけるレーザ光の発振波長とは異なるものにして、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層とを設けたことを特徴とする。第2調整層は、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されると共に、第1調整層と第2調整層と反射層とによって多重反射による干渉を発生させて、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層とすることができる。また、第2調整層は、活性層領域で発生したレーザ光の出射中心の少なくとも周辺部であって、少なくとも一方の反射層と第1調整層との間に積層され、少なくとも一方の反射層と第1調整層とで反射されたレーザ光が入射されると共に、第1調整層と第2調整層と反射層とによって共振する波長をレーザ光の発振波長よりも短波長側にシフトさせると共に、レーザ光の出射中心の周辺部におけるレーザ光の発振波長に対する実効屈折率を低下させる透光性の第2調整層としてもよい。

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**